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EDEXCEL INTERNATIONAL GCSE (9–1)

SCIENCE DOUBLE AWARD

Student Book

Brian Arnold, Phil Bradfield, Jim Clark, Penny Johnson, Steve Owen, Steve Potter, Steve Woolley, Rachel Yu

Pearson

eBook included

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BIOLOGY
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PHYSICS
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ABOUT THIS BOOK

This book is written for students following the Pearson Edexcel International GCSE (9–1) Science Double Award specification. You will need to study all of the content in this book for your examinations, except anything in Extension boxes.

In each unit of this book, there are concise explanations and worked examples, plus numerous exercises that will help you build up confidence. The book also describes the methods for carrying out all of the required practicals.

The language throughout this textbook is graded for speakers of English as an additional language (EAL), with advanced Science-specific terminology highlighted and defined in the glossaries on the eBook. A list of command words at the back of the book will help you to learn the language you will need in your examinations.

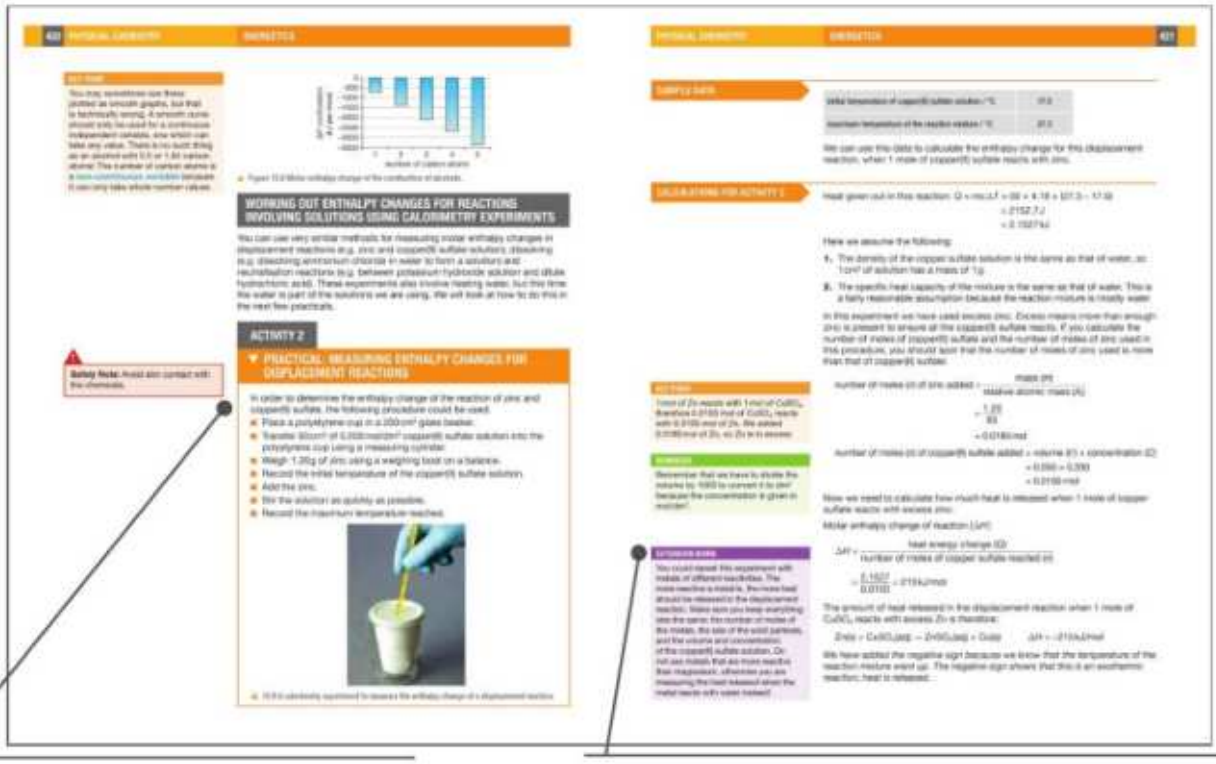
You will also find that questions in this book have Progression icons and Skills tags. The Progression icons refer to Pearson's Progression scale. This scale – from 1 to 12 – tells you what level you have reached in your learning and will help you to see what you need to do to progress to the next level. Furthermore, Edexcel have developed a Skills grid showing the skills you will practise throughout your time on the course. The skills in the grid have been matched to questions in this book to help you see which skills you are developing. You can find Pearson's Progression scale at www.pearsonglobalschools.com/igscienceprogression along with guidelines on how to use it. Edexcel's skills grid can be found on their website.

Learning Objectives show what you will learn in each chapter.

Unit boxes tell you which units – for example, metres, grams and seconds – you will need to know and use for the study of a topic.

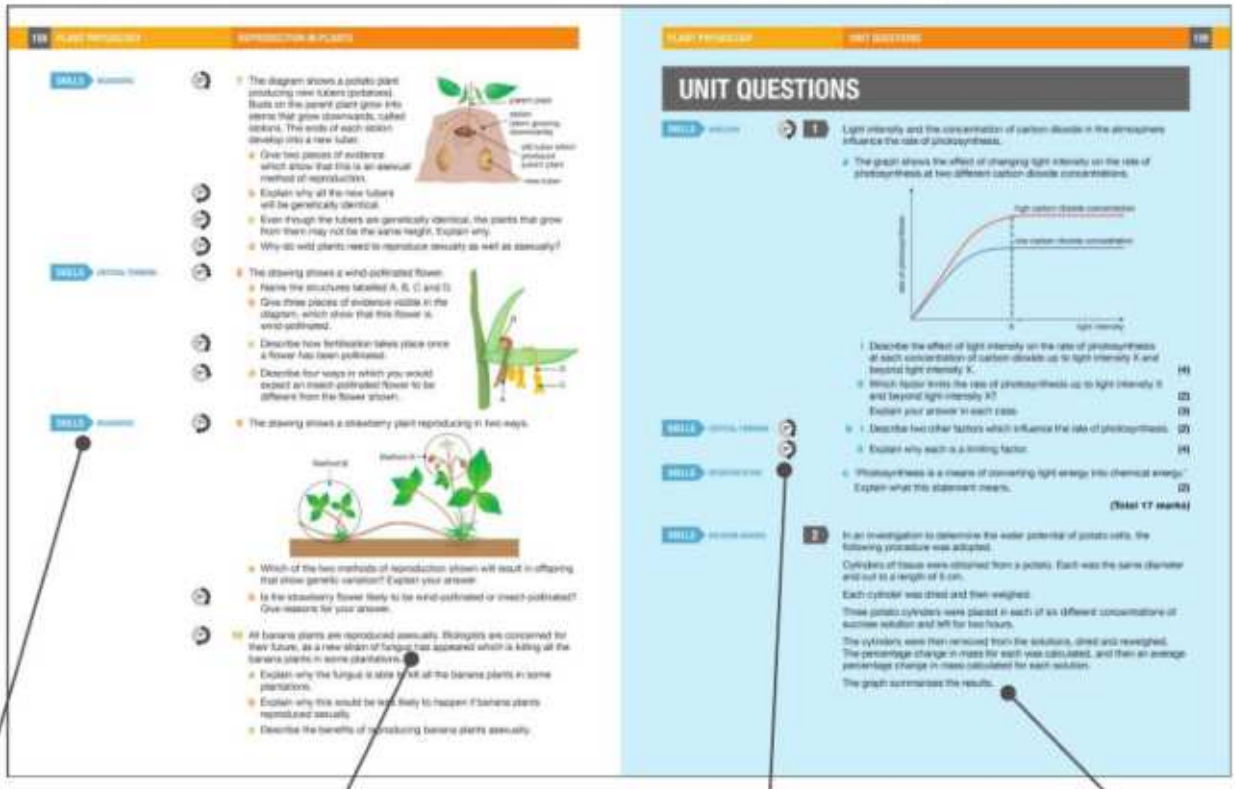


Looking Ahead tells you what you would learn if you continued your study of Science to a higher level, such as International A Level.



Practicals describe the methods for carrying out all of the practicals you will need to know for your examination.

Extension work boxes include content that is not on the specification and which you do not have to learn for your examination. However, it will help to extend your understanding of the topic.



Skills tags tell you which skills you are practising in each question.

Chapter Questions test your knowledge of the topic in that chapter.

Progression icons show the level of difficulty according to the Pearson International GCSE Science Progression Scale.

Unit Questions test your knowledge of the whole unit and provide quick, effective feedback on your progress.

ASSESSMENT OVERVIEW

The following tables give an overview of the assessment for this course.

We recommend that you study this information closely to help ensure that you are fully prepared for this course and know exactly what to expect in the assessment.

BIOLOGY PAPER 1	SPECIFICATION	PERCENTAGE	MARK	TIME	AVAILABILITY
Written examination paper Paper code 4SD0/1B Externally set and assessed by Edexcel	Science Double Award	33.3%	110	2 hours	January and June examination series First assessment June 2019
CHEMISTRY PAPER 1	**SPECIFICATION**	**PERCENTAGE**	**MARK**	**TIME**	**AVAILABILITY**
Written examination paper Paper code 4SD0/1C Externally set and assessed by Edexcel	Science Double Award	33.3%	110	2 hours	January and June examination series First assessment June 2019
PHYSICS PAPER 1	**SPECIFICATION**	**PERCENTAGE**	**MARK**	**TIME**	**AVAILABILITY**
Written examination paper Paper code 4SD0/1P Externally set and assessed by Edexcel	Science Double Award	33.3%	110	2 hours	January and June examination series First assessment June 2019

ASSESSMENT OBJECTIVES AND WEIGHTINGS

ASSESSMENT OBJECTIVE	DESCRIPTION	% IN INTERNATIONAL GCSE
AO1	Knowledge and understanding of science	38%–42%
AO2	Application of knowledge and understanding, analysis and evaluation of science	38%–42%
AO3	Experimental skills, analysis and evaluation of data and methods in science	19%–21%

EXPERIMENTAL SKILLS

In the assessment of experimental skills, students may be tested on their ability to:

- solve problems set in a practical context
- apply scientific knowledge and understanding in questions with a practical context
- devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- demonstrate or describe appropriate experimental and investigative methods, including safe and skilful practical techniques
- make observations and measurements with appropriate precision, record these methodically and present them in appropriate ways
- identify independent, dependent and control variables
- use scientific knowledge and understanding to analyse and interpret data to draw conclusions from experimental activities that are consistent with the evidence
- communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- assess the reliability of an experimental activity
- evaluate data and methods taking into account factors that affect accuracy and validity.

CALCULATORS

Students are permitted to take a suitable calculator into the examinations. Calculators with QWERTY keyboards or that can retrieve text or formulae will not be permitted.

BIOLOGY UNIT 1 ORGANISMS AND LIFE PROCESSES

All living organisms are composed of microscopic units known as cells. These building blocks of life have a number of features in common, which allow them to grow, reproduce, and generate more organisms. In Chapter 1 we start by looking at the structure and function of cells, and the essential life processes that go on within them. Despite the fact that cells are similar in structure, there are many millions of different species of organisms. Chapter 2 looks at the diversity of living things and how we can classify them into groups on the basis of the features that they show.



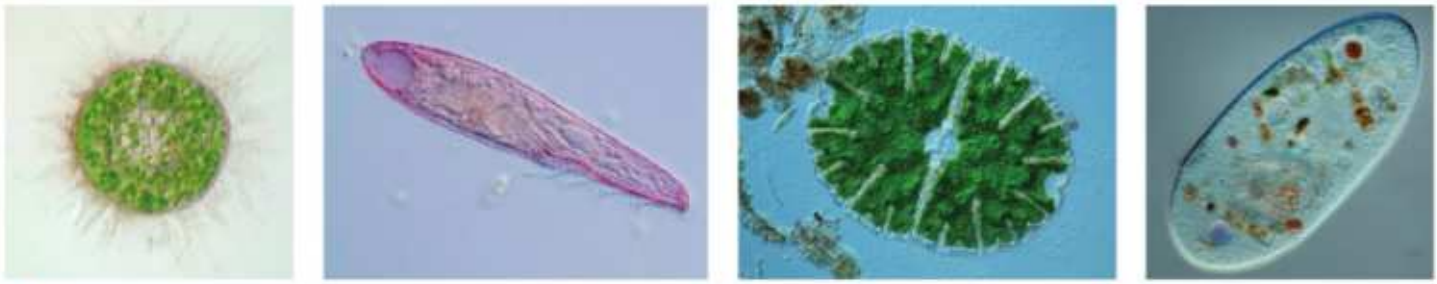
1 LIFE PROCESSES

There are structural features that are common to the cells of all living organisms. In this chapter you will find out about these features and look at some of the processes that keep cells alive.

LEARNING OBJECTIVES

- Understand the characteristics shared by living organisms
- Describe cell structures and their functions, including the nucleus, cytoplasm, cell membrane, cell wall, mitochondria, chloroplasts, ribosomes and vacuole
- Know the similarities and differences in the structures of plant and animal cells
- Understand the role of enzymes as biological catalysts in metabolic reactions
- Understand how temperature changes can affect enzyme function, including changes to the shape of the active site
- Understand how enzyme function can be affected by changes in pH altering the active site
- Investigate how enzyme activity can be affected by changes in temperature
- Describe the differences between aerobic and anaerobic respiration
- Understand how the process of respiration produces ATP in living organisms
- Know that ATP provides energy for cells
- Know the word equation and balanced chemical symbol equation for aerobic respiration
- Know the word equations for anaerobic respiration
- Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms
- Understand the processes of diffusion, osmosis and active transport by which substances move into and out of cells
- Understand how factors affect the rate of movement of substances into and out of cells
- Investigate diffusion in a non-living system (agar jelly)
- Describe the levels of organisation within organisms – organelles, cells, tissues, organ systems

All living organisms are composed of units called **cells**. The simplest organisms are made from single cells (Figure 1.1) but more complex plants and animals are composed of millions of cells. In many-celled (**multicellular**) organisms, there may be hundreds of different types of cells with different structures. They are specialised so that they can carry out particular functions in the animal or plant. Despite all the differences, there are basic features that are the same in all cells.



▲ Figure 1.1 Many simple organisms have 'bodies' made from single cells. Here are four examples.

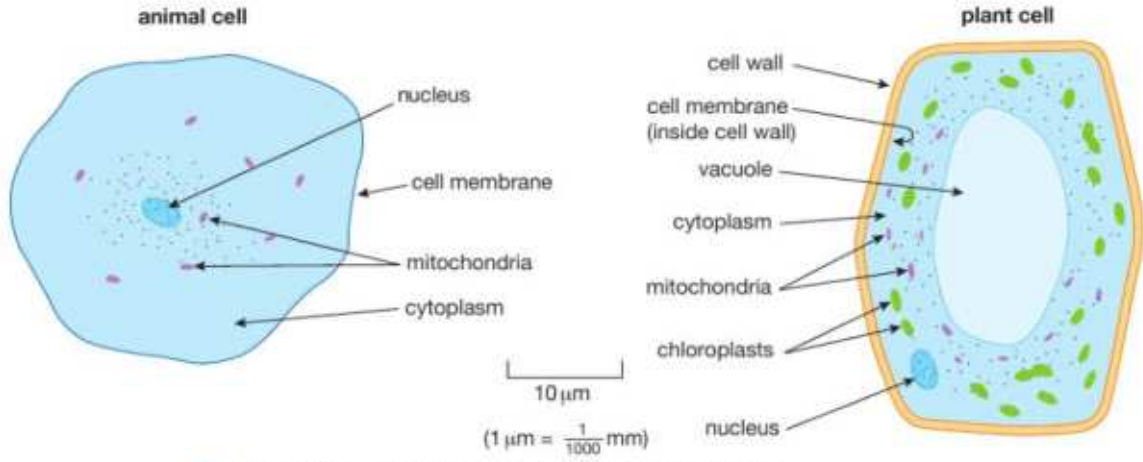
There are eight life processes which take place in most living things. Organisms:

- require nutrition – plants make their own food, animals eat other organisms
- respire – release energy from their food
- excrete – get rid of waste products
- respond to stimuli – are sensitive to changes in their surroundings
- move – by the action of muscles in animals, and slow growth movements in plants
- control their internal conditions – maintain a steady state inside the body
- reproduce – produce offspring
- grow and develop – increase in size and complexity, using materials from their food.

CELL STRUCTURE

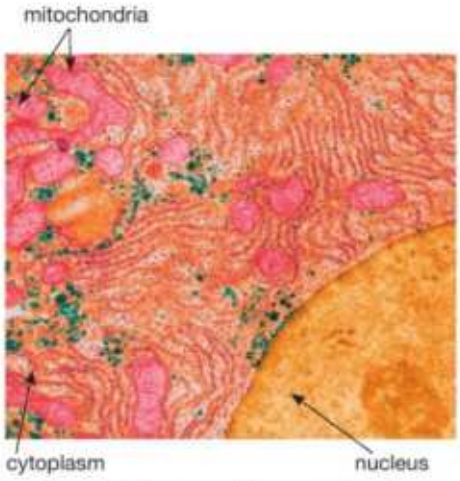
This part of the book describes the cell structure of 'higher' organisms such as animals, plants and fungi. The cells of bacteria are simpler in structure and will be described in Chapter 2.

Most cells contain certain parts such as the nucleus, cytoplasm and cell membrane. Some cells have structures missing, for instance red blood cells are unusual in that they have no nucleus. The first chapter in a biology textbook will usually present diagrams of 'typical' plant and animal cells. In fact, there is really no such thing as a 'typical' cell. Humans, for example, are composed of hundreds of different kinds of cells – from nerve cells to blood cells, skin cells to liver cells. What we really mean by a 'typical' cell is a general diagram that shows all the features that you will find in most cells (Figure 1.2). However, not all these are present in *all* cells – for example the cells in the parts of a plant that are not green do not contain chloroplasts.



▲ Figure 1.2 The structure of a 'typical' animal and plant cell.

The living material that makes up a cell is called **cytoplasm**. It has a texture rather like sloppy jelly, in other words somewhere between a solid and a liquid. Unlike a jelly, it is not made of one substance but is a complex material made of many different structures. You can't see many of these structures under an ordinary light microscope. An electron microscope has a much higher magnification and can show the details of these structures, which are called **organelles** (Figure 1.3).



▲ Figure 1.3 The organelles in a cell can be seen using an electron micropscope.

The largest organelle in the cell is the **nucleus**. Nearly all cells have a nucleus. The few types that don't are usually dead (e.g. the xylem vessels in a stem, Chapter 11) or don't live for very long (e.g. red blood cells, Chapter 5). The nucleus controls the activities of the cell. It contains **chromosomes** (46 in human cells) which carry the genetic material, or **genes**. Genes control the activities in the cell by determining which proteins the cell can make. The DNA remains in the nucleus, but the instructions for making proteins are carried out of the nucleus to the cytoplasm, where the proteins are assembled on tiny structures called **ribosomes**. A cell contains thousands of ribosomes, but they are too small to be seen through a light microscope.

One very important group of proteins found in cells are **enzymes.** Enzymes control the chemical reactions that take place in the cytoplasm.

All cells are surrounded by a **cell membrane**, sometimes called the cell *surface* membrane to distinguish it from other membranes inside the cell. This is a thin layer like a 'skin' on the surface of the cell. It forms a boundary between the cytoplasm of the cell and the outside. However, it is not a complete barrier. Some chemicals can pass into the cell and others can pass out. We say that the membrane is **partially permeable**. The membrane can go further than this and actually *control* the movement of some substances – it is **selectively permeable**.

One organelle that is found in the cytoplasm of all living cells is the **mitochondrion** (plural mitochondria). In cells that need a lot of energy such as muscle or nerve cells, there are many mitochondria. This gives us a clue to their function. They carry out some of the reactions of **respiration** (see page 11) releasing energy that the cell can use. Most of the energy from respiration is released in the mitochondria.

PLANT CELLS

All of the structures you have seen so far are found in both animal and plant cells. However, some structures are only ever found in plant cells. There are three in particular – the cell wall, a permanent vacuole and chloroplasts.

The **cell wall** is a layer of non-living material that is found outside the cell membrane of plant cells. It is made mainly of a carbohydrate called **cellulose**, although other chemicals may be added to the wall in some cells. Cellulose is a tough material that helps the cell keep its shape and is one reason why the 'body' of a plant has a fixed shape. Animal cells do not have a cell wall and tend to be more variable in shape. Plant cells absorb water, producing an internal pressure that pushes against adjacent cells, giving the plant support (see Chapter 11). Without a cell wall strong enough to resist these pressures, this method of support would be impossible. The cell wall is porous, so it is not a barrier to water or dissolved substances. We call it *freely permeable*.

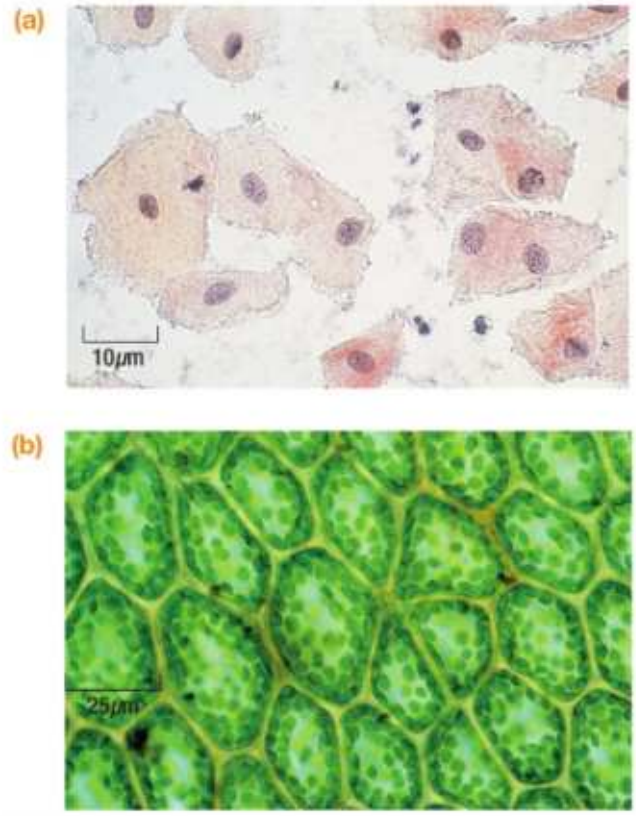
Mature (fully grown) plant cells often have a large central space surrounded by a membrane, called a **vacuole**. This vacuole is a permanent feature of the cell. It is filled with a watery liquid called cell sap, which is a store of dissolved sugars, mineral ions and other solutes. Animal cells do contain vacuoles, but they are only small, temporary structures.

Cells of the green parts of plants, especially the leaves, contain another very important organelle, the **chloroplast**. Chloroplasts absorb light energy to make food in the process of photosynthesis (see Chapter 10). They contain a green pigment called **chlorophyll**. Cells from the parts of a plant that are not green, such as the flowers, roots and woody stems, have no chloroplasts.

KEY POINT

Nearly all cells contain cytoplasm, a nucleus, a cell membrane and mitochondria. As well as these structures, plant cells have a cell wall and a permanent vacuole, and plant cells that photosynthesise contain chloroplasts.

Figure 1.4 shows some animal and plant cells seen through the light microscope.



▲ Figure 1.4 (a) Cells from the lining of a human cheek. (b) Cells from the photosynthetic tissue of a leaf.

ENZYMES: CONTROLLING REACTIONS IN THE CELL

KEY POINT

The chemical reactions taking place in a cell are known as metabolic reactions. The sum of all the metabolic reactions is known as the **metabolism** of the cell. The function of enzymes is to catalyse metabolic reactions.

KEY POINT

You have probably heard of enzymes being involved in digestion of food. In the intestine enzymes are secreted onto the food to break it down. These are called *extracellular* enzymes, which means they function 'outside cells'. However, most enzymes stay inside cells and carry out their function there; they are *intracellular*. You will find out about digestive enzymes in Chapter 4.

KEY POINT

Secretion is the release of a fluid or substances from a cell or tissue.

The chemical reactions that take place in a cell are controlled by a group of proteins called enzymes. Enzymes are biological **catalysts**. A catalyst is a chemical which speeds up a reaction without being used up itself. It takes part in the reaction, but afterwards is unchanged and free to catalyse more reactions. Cells contain hundreds of different enzymes, each catalysing a different reaction. This is how the activities of a cell are controlled – the nucleus contains the genes, which control the production of enzymes, which then catalyse reactions in the cytoplasm:

genes → proteins (enzymes) → catalyse reactions

Everything a cell does depends on which enzymes it can make, which in turn depends on which genes in its nucleus are working.

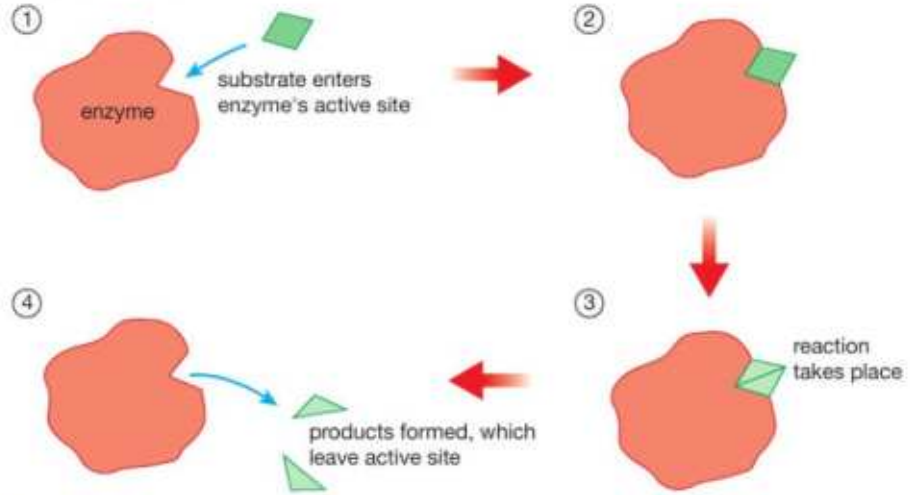
What hasn't been mentioned is why enzymes are needed at all. They are necessary because the temperatures inside organisms are low (e.g. the human body temperature is about 37 °C) and without catalysts, most of the reactions that happen in cells would be far too slow to allow life to go on. The reactions can only take place quickly enough when enzymes are present to speed them up.

It is possible for there to be thousands of different sorts of enzymes because they are proteins, and protein molecules have an enormous range of structures and shapes (see Chapter 4).

The molecule that an enzyme acts on is called its **substrate**. Each enzyme has a small area on its surface called the **active site**. The substrate attaches to the active site of the enzyme. The reaction then takes place and products are formed. When the substrate joins up with the active site it lowers the energy needed for the reaction to start, allowing the products to be formed more easily.

Enzymes also catalyse reactions where large molecules are built up from smaller ones. In this case, several substrate molecules attach to the active site, the reaction takes place and the larger product molecule is formed. The product then leaves the active site.

The substrate fits into the active site of the enzyme like a key fitting into a lock. Just as a key will only fit one lock, a substrate will only fit into the active site of a particular enzyme. This is known as the **lock and key model** of enzyme action. It is the reason why enzymes are *specific*, i.e. an enzyme will only catalyse one reaction.



▲ Figure 1.5 Enzymes catalyse reactions at their active site. This acts like a 'lock' to the substrate 'key'. The substrate fits into the active site, and products are formed. This happens more easily than without the enzyme – so enzymes act as catalysts.

After an enzyme molecule has catalysed a reaction, the product is released from the active site, and the enzyme is free to act on more substrate molecules.

FACTORS AFFECTING ENZYMES

KEY POINT

'Optimum' temperature means the 'best' temperature, in other words the temperature at which the reaction takes place most rapidly.

DID YOU KNOW?

Kinetic energy is the energy an object has because of its movement. The molecules of enzyme and substrate are moving faster, so they have more kinetic energy.

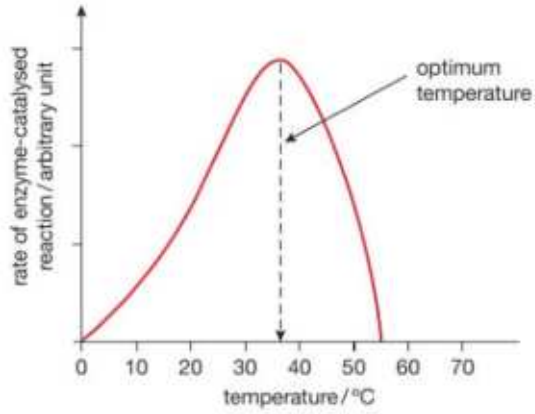
A number of factors affect the activity of enzymes. The rate of reaction may be increased by raising the concentration of the enzyme or the substrate. Two other factors that affect enzymes are temperature and pH.

TEMPERATURE

The effect of temperature on the action of an enzyme is easiest to see as a graph, where we plot the rate of the reaction against temperature (Figure 1.6).

Enzymes in the human body have evolved to work best at body temperature (37 °C). The graph in Figure 1.6 shows a peak on the curve at this temperature, which is called the *optimum temperature* for the enzyme.

As the enzyme is heated up to the optimum temperature, the rise in temperature increases the rate of reaction. This is because higher temperatures give the molecules of the enzyme and the substrate more kinetic energy, so they collide more often. More collisions means that the reaction will take place more frequently.



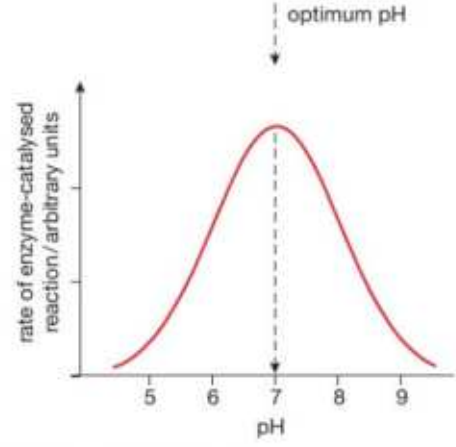
▲ Figure 1.6 Effect of temperature on the action of an enzyme.

However, above the optimum, temperature starts to have another effect. Enzymes are made of protein, and proteins are broken down by heat. From 40 °C upwards, the heat destroys the enzyme. We say that it is denatured. You can see the effect of **denaturing** when you boil an egg. The egg white is made of protein, and turns from a clear runny liquid into a white solid as the heat denatures the protein. Denaturing changes the shape of the active site so that the substrate will no longer fit into it. Denaturing is permanent – the enzyme molecules will no longer catalyse the reaction.

Not all enzymes have an optimum temperature near 37 °C, only those of animals such as mammals and birds, which all have body temperatures close to this value. Enzymes have evolved to work best at the normal body temperature of the organism. Bacteria that always live at an average temperature of 10 °C will probably have enzymes with an optimum temperature near 10 °C.

pH

The pH around the enzyme is also important. The pH inside cells is neutral (pH 7) and most enzymes have evolved to work best at this pH. At extremes of pH either side of neutral, the enzyme activity decreases, as shown in Figure 1.7. The pH at which the enzyme works best is called its *optimum pH*. Either side of the optimum, the pH affects the structure of the enzyme molecule and changes the shape of its active site, so that the substrate will not fit into it so well.



▲ Figure 1.7 Most enzymes work best at a neutral pH.

KEY POINT

Although most enzymes work best at a neutral pH, a few have an optimum below or above pH 7. The stomach produces hydrochloric acid, which makes its contents very acidic (see Chapter 4). Most enzymes stop working at a low pH, but the stomach makes an enzyme called pepsin which has an optimum pH of about 2, so that it is adapted to work well in these unusually acidic surroundings.

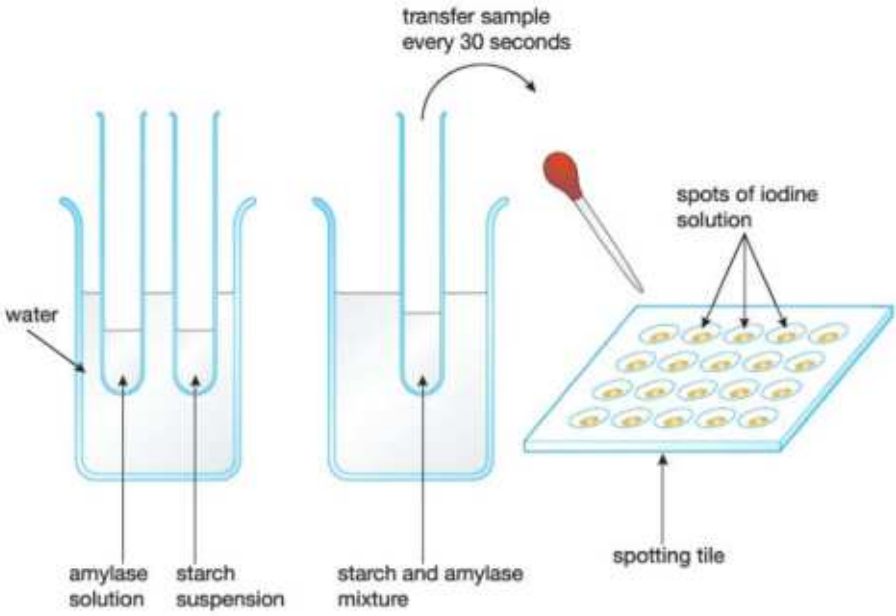
Safety note: Wear eye protection and avoid skin contact with the liquids. Amylase is hazardous to the eyes.

ACTIVITY 1

▼ PRACTICAL: AN INVESTIGATION INTO THE EFFECT OF TEMPERATURE ON THE ACTIVITY OF AMYLASE

The digestive enzyme amylase breaks down starch into the sugar maltose. If the speed at which the starch disappears is recorded, this is a measure of the activity of the amylase.

Figure 1.8 shows apparatus which can be used to record how quickly the starch is used up.



▲ Figure 1.8 Investigating the breakdown of starch by amylase at different temperatures.

Spots of iodine solution are placed into the dips on the spotting tile. Using a syringe, 5 cm^3 of starch suspension is placed in one boiling tube, and 5 cm^3 of amylase solution in another tube, using a different syringe. The beaker is filled with water at 20 °C. Both boiling tubes are placed in the beaker of water for 5 minutes, and the temperature recorded.

The amylase solution is then poured into the starch suspension, leaving the tube containing the mixture in the water bath. Immediately, a small sample of the mixture is removed from the tube with a pipette and added to the first drop of iodine solution on the spotting tile. The colour of the iodine solution is recorded.

A sample of the mixture is taken every 30 seconds for 10 minutes and tested for starch as above, until the iodine solution remains yellow, showing that all the starch is used up.

The experiment is repeated, maintaining the water bath at different temperatures between 20 °C and 60 °C. A set of results is shown in the table below.

	Colour of mixture at different temperatures / (°C)				
Time / min	20	30	40	50	60
0.0	Blue-black	Blue-black	Blue-black	Blue-black	Blue-black
0.5	Blue-black	Blue-black	Brown	Blue-black	Blue-black
1.0	Blue-black	Blue-black	Yellow	Blue-black	Blue-black
1.5	Blue-black	Blue-black	Yellow	Blue-black	Blue-black
2.0	Blue-black	Blue-black	Yellow	Brown	Blue-black
2.5	Blue-black	Blue-black	Yellow	Brown	Blue-black
3.0	Blue-black	Blue-black	Yellow	Brown	Blue-black
3.5	Blue-black	Blue-black	Yellow	Yellow	Blue-black
4.0	Blue-black	Blue-black	Yellow	Yellow	Blue-black
5.5	Blue-black	Blue-black	Yellow	Yellow	Blue-black
6.0	Blue-black	Brown	Yellow	Yellow	Blue-black
6.5	Blue-black	Brown	Yellow	Yellow	Blue-black
7.0	Blue-black	Yellow	Yellow	Yellow	Blue-black
7.5	Blue-black	Yellow	Yellow	Yellow	Brown
8.0	Blue-black	Yellow	Yellow	Yellow	Brown
8.5	Brown	Yellow	Yellow	Yellow	Yellow
9.0	Brown	Yellow	Yellow	Yellow	Yellow
9.5	Yellow	Yellow	Yellow	Yellow	Yellow
10.0	Yellow	Yellow	Yellow	Yellow	Yellow

The rate of reaction can be calculated from the time taken for the starch to be fully broken down, as shown by the colour change from blue-black to yellow. For example, at 50 °C the starch had all been digested after 3.5 minutes. The rate is found by dividing the volume of the starch (5 cm^3) by the time:

$$\text{Rate} = \frac{5.0\,cm^3}{3.5\,min} = 1.4\ cm^3 \text{ per min}$$

Plotting a graph of rate against temperature should produce a curve similar to the one shown in Figure 1.6. Try this, using the results in the table. Better still, you may be able to do this experiment and provide your own results.

If the curve doesn't turn out quite like the one in Figure 1.6, can you suggest why this is? How could you improve the experiment to get more reliable results?

HOW THE CELL GETS ITS ENERGY

A cell needs a source of energy in order to be able to carry out all the processes needed for life. It gets this energy by breaking down food molecules to release the stored chemical energy that they contain. This process is called respiration. Many people think that respiration means the same as 'breathing', but although there are links between the two processes, the biological meaning of respiration is very different.

KEY POINT

Respiration is called an *oxidation* reaction, because oxygen is used to break down food molecules.

Respiration happens in all the cells of our body. Oxygen is used to oxidise food, and carbon dioxide (and water) are released as waste products. The main food oxidised is a sugar called **glucose**. Glucose contains stored chemical energy that can be converted into other forms of energy that the cell can use. It is rather like burning a fuel to get the energy out of it, except that burning releases most of the energy as heat. Respiration releases some heat energy, but most is used to make a substance called ATP (see below). The energy stored in the ATP molecules can then be used for a variety of purposes, such as:

- contraction of muscle cells, producing movement
- active transport of molecules and ions (see page 17)
- building large molecules, such as proteins
- cell division.

The energy released as heat is also used to maintain a constant body temperature in mammals and birds (see Chapter 8).

The overall reaction for respiration is:

glucose	+	oxygen	→	carbon dioxide	+	water	(+ energy)
$C_6H_{12}O_6$	+	$6O_2$	→	$6CO_2$	+	$6H_2O$	(+ energy)

DID YOU KNOW?

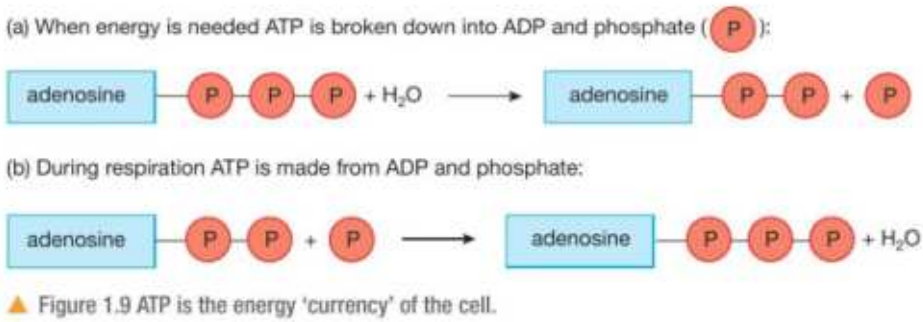
Carbon from the respired glucose passes out into the atmosphere as carbon dioxide. The carbon can be traced through this pathway using a radioactive form of carbon called carbon-14.

This is called **aerobic respiration**, because it uses oxygen. Aerobic respiration happens in the cells of humans and those of animals, plants and many other organisms. It is important to realise that the equation above is only a *summary* of the process. It actually takes place gradually, as a sequence of small steps, which release the energy of the glucose in small amounts. Each step in the process is catalysed by a different enzyme. The later steps in the process are the aerobic ones, and these release the most energy. They happen in the mitochondria of the cell.

ATP – THE ENERGEY 'CURRENCY' OF THE CELL

Respiration releases energy while other cell processes use it up. Cells have a way of passing the energy from respiration to the other processes that need it. They do this using a chemical called **adenosine triphosphate** or **ATP**. ATP is present in all living cells.

ATP is composed of an organic molecule called adenosine attached to three phosphate groups. In a cell, ATP can be broken down losing one phosphate group and forming adenosine diphosphate or ADP (Figure 1.9 (a)).



▲ Figure 1.9 ATP is the energy 'currency' of the cell.

When this reaction takes place, chemical energy is released and can be used to drive metabolic processes that need it.

During respiration the opposite happens – energy from the oxidation of glucose is used to drive the reverse reaction and a phosphate is added onto ADP (Figure 1.9 (b)).

ATP is often described as the energy 'currency' of the cell. It transfers energy between the process that releases it (respiration) and the processes in a cell that use it up.

ANAEROBIC RESPIRATION

There are some situations where cells can respire *without* using oxygen. This is called **anaerobic respiration**. In anaerobic respiration, glucose is not completely broken down, so less energy is released. The advantage of anaerobic respiration is that it can occur in situations where oxygen is in short supply. Two important examples of this are in yeast cells and muscle cells.

Yeasts are single-celled fungi. They are used in processes such as baking bread. When yeast cells are prevented from getting enough oxygen, they stop respiring aerobically and start to respire anaerobically instead. The glucose is partly broken down into ethanol (alcohol) and carbon dioxide:

glucose → ethanol + carbon dioxide (+ some energy)

This process is described in more detail in Chapter 21.

Think about the properties of ethanol – it makes a good fuel and will burn to produce a lot of heat, so it still has a lot of chemical energy 'stored' in it.

Muscle cells can also respire anaerobically when they are short of oxygen. If muscles are overworked, the blood cannot reach them fast enough to deliver enough oxygen for aerobic respiration. This happens when a person does a 'burst' of activity, such as a sprint, or quickly lifting a heavy weight. This time the glucose is broken down into a substance called **lactate**:

glucose → lactate (+ some energy)

Anaerobic respiration provides enough energy to keep the overworked muscles going for a short period. During the exercise, the level of lactate rises in the muscle cells and bloodstream.

DID YOU KNOW?

It was once thought that lactate was toxic and caused muscle fatigue. We now know that this is *not* true. In fact physiologists have shown that lactate actually *delays* muscle fatigue. Fatigue is caused by other changes that happen in the muscles during exercise.

DID YOU KNOW?

Lactate is sometims called lactic acid.

After the exercise the lactate is respired aerobically in the mitochondria. The volume of oxygen needed to completely oxidise the lactate that builds up in the body during anaerobic respiration is called the **oxygen debt**.

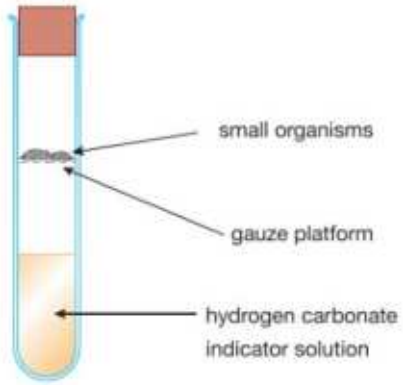
ACTIVITY 2

▼ PRACTICAL: DEMONSTRATION OF THE PRODUCTION OF CARBON DIOXIDE BY SMALL LIVING ORGANISMS

Safety note: Wear eye protection, treat all living organisms with care and avoid skin contact.

Hydrogen carbonate indicator solution is normally orange, but turns yellow if carbon dioxide is added to it. The indicator is sensitive to small changes in carbon dioxide concentration, and can be used to show production of carbon dioxide by small organisms such as woodlice, maggots (fly larvae) or germinating seeds.

The organisms are placed in a stoppered boiling tube with the indicator, as shown in Figure 1.10. The gauze platform supports the organisms above the hydrogen carbonate indicator solution and stops them from coming into contact with the chemical.



▲ Figure 1.10 Testing for carbon dioxide production by small organisms.

Of the three species of organisms mentioned above, which do you think would change the colour of the indicator most quickly? If you are able to observe each of the organisms, this might help with your prediction.

When you have made your prediction (called a 'hypothesis'), plan an investigation to test it. Take care to consider the variables that need to be **controlled variable**, and don't forget to include a description of a fourth tube that you would need to set up as the experimental Control (see Appendix A for an explanation of these terms).

It may be possible for you to carry out the investigation using similar apparatus and organisms.

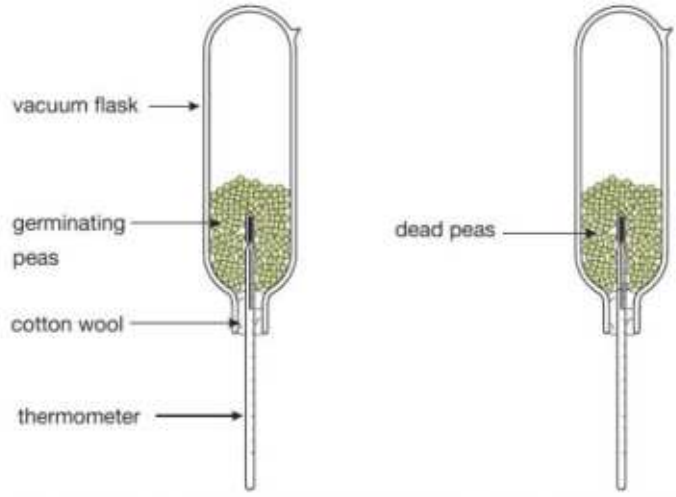
Safety note: Eye protection should be worn when using bleach to wash the peas and skin contact avoided.

ACTIVITY 3

▼ PRACTICAL: DEMONSTRATION THAT HEAT IS PRODUCED BY RESPIRATION

Some peas are soaked in water for 24 hours, so that they start to germinate. A second batch of peas is boiled, to kill them. Each set of peas is washed in a 1% bleach solution, which acts as a disinfectant, killing any bacteria present on the surface of the peas. The peas are then rinsed twice in distilled water to remove any traces of bleach.

Each batch of peas is placed in an inverted vacuum flask as shown in Figure 1.11, leaving some air in each flask. A vacuum flask insulates its contents, so that any small temperature change inside the flask can be measured.



▲ Figure 1.11 Experiment to show that heat is produced during respiration in germinating peas.

The seeds produce carbon dioxide gas, which is denser than air. The inverted flasks and cotton wool allow this to escape. It might otherwise kill the peas.

The apparatus is left set up for a couple of days, and the temperature inside each flask measured at the start and end of the experiment.

The following results were obtained from this experiment:

Temperature in both flasks at the start = 21 °C

Temperature in flask with dead peas at the end = 21 °C

Temperature in flask with living peas at the end = 24 °C

Can you explain these results? Why is it necessary to kill any microorganisms on the surface of the peas? Explain the importance of the flask containing dead peas.

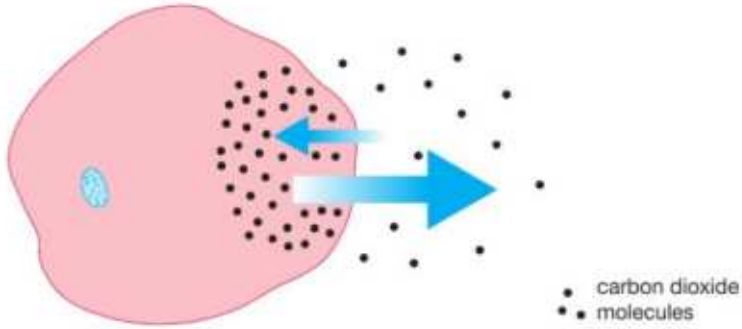
MOVEMENT OF MATERIALS IN AND OUT OF CELLS

Cell respiration shows the need for cells to be able to take in certain substances from their surroundings, such as glucose and oxygen, and get rid of others, such as carbon dioxide and water. As you have seen, the cell surface membrane can control which chemicals can pass in and out – it is described as selectively permeable.

There are three main ways that molecules and ions can move through the membrane. They are diffusion, active transport and osmosis.

DIFFUSION

Many substances can pass through the membrane by **diffusion**. Diffusion happens when a substance is more concentrated in one place than another. For example, if the cell is making carbon dioxide by respiration, the concentration of carbon dioxide inside the cell will be higher than outside. This difference in concentration is called a concentration gradient. The molecules of carbon dioxide are constantly moving about because of their kinetic energy. The cell membrane is permeable to carbon dioxide, so the molecules can move in either direction through it. Since there is a higher concentration of carbon dioxide molecules inside the cell than outside, over time, more molecules will move from inside to outside than move in the other direction. We say that there is a *net* movement of the molecules out of the cell (Figure 1.12).



▲ Figure 1.12 Carbon dioxide is produced by respiration, so its concentration builds up inside the cell. Although the carbon dioxide molecules diffuse in both directions across the cell membrane, the overall (net) movement is out of the cell, down the concentration gradient.

KEY POINT

Diffusion is the net movement of particles (molecules or ions) from a region of high concentration to a region of low concentration, i.e. down a concentration gradient.

The opposite happens with oxygen. Respiration uses up oxygen, so there is a concentration gradient of oxygen from outside to inside the cell. There is therefore a net movement of oxygen *into* the cell by diffusion.

The rate of diffusion is affected by various factors.

- The concentration gradient. Diffusion happens more quickly when there is a steep concentration gradient (i.e. a big difference in concentrations between two areas).
- The surface area to volume ratio. A larger surface area in proportion to the volume will increase the rate.
- The distance. The rate is decreased if the distance over which diffusion has to take place is greater.
- The temperature. The rate is greater at higher temperatures. This is because a high temperature provides the particles with more kinetic energy.

Safety note: Wear eye protection and avoid all skin contact with the acid and the dyed agar blocks.

ACTIVITY 4

▼ PRACTICAL: DEMONSTRATION OF DIFFUSION IN A JELLY

Agar is a jelly that is used for growing cultures of bacteria. It has a consistency similar to the cytoplasm of a cell. Like cytoplasm, it has a high water content. Agar can be used to show how substances diffuse through a cell.

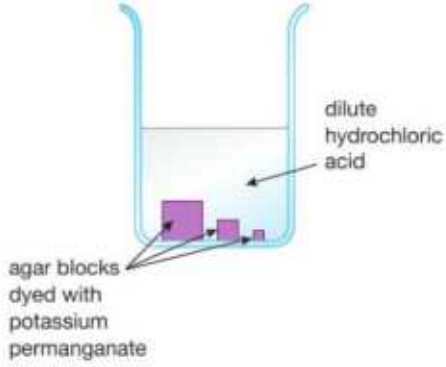
This demonstration uses the reaction between hydrochloric acid and potassium permanganate solution. When hydrochloric acid comes into contact with potassium permanganate, the purple colour of the permanganate disappears.

A Petri dish is prepared which contains a 2 cm deep layer of agar jelly, dyed purple with potassium permanganate. Three cubes of different sizes are cut out of the jelly, with side lengths 2 cm, 1 cm and 0.5 cm. The cubes have different volumes and total surface areas. They also have a different surface area to volume ratio, as shown in the table below.

Length of side of cube / cm	Volume of cube / cm^3 (length × width × height)	Surface area of cube / cm^2 (length × width of one side) × 6	Ratio of surface area to volume of cube (surface area divided by volume)
2	(2 × 2 × 2) = 8	(2 × 2) × 6 = 24	24/8 = 3
1	(1 × 1 × 1) = 1	(1 × 1) × 6 = 6	6/1 = 6
0.5	(0.5 × 0.5 × 0.5) = 0.125	(0.5 × 0.5) × 6 = 1.5	1.5/0.125 = 12

Notice that the smallest cube has the largest surface area to volume ratio. The same is true of cells – a small cell has a larger surface area to volume ratio than a large cell.

The cubes are carefully dropped, at the same time, into a beaker of dilute hydrochloric acid (Figure 1.13).



▶ Figure 1.13 Investigating diffusion in a jelly.

The time taken for each cube to turn colourless is noted.

Which cube would be the first to turn colourless and which the last? Explain the reasoning behind your prediction.

If the three cubes represented cells of different sizes, which cell would have the most difficulty in obtaining substances by diffusion?

It may be possible for you to try this experiment, using similar apparatus.

ACTIVE TRANSPORT

Diffusion happens because of the kinetic energy of the particles. It does not need an 'extra' source of energy from respiration. However, sometimes a cell needs to take in a substance when there is very little of that substance outside the cell, in other words *against* a concentration gradient. It can do this by another process, called **active transport**.

During active transport a cell uses energy from respiration to take up substances, rather like a pump uses energy to move a liquid from one place to another. In fact, biologists speak of the cell 'pumping' ions or molecules in or out. The pumps are large protein molecules located in the cell membrane, and they are driven by the breakdown of ATP. An example of a place where this happens is in the human small intestine, where some glucose in the gut is absorbed into the cells lining the intestine by active transport. The roots of plants also take up certain mineral ions in this way. Cells use active transport to control the uptake of many substances.

KEY POINT

Active transport is the movement of substances against a concentration gradient, using energy from respiration.

OSMOSIS

Water moves across cell membranes by a special sort of diffusion, called **osmosis**. Osmosis happens when the total concentrations of all dissolved substances inside and outside the cell are different. Water will move across the membrane from the more dilute solution to the more concentrated one. Notice that this is still obeying the rules of diffusion – the water moves from where there is a higher concentration of *water* molecules to a lower concentration of *water* molecules. Osmosis can only happen if the membrane is permeable to water but not to some other solutes. We say that it is partially permeable.

Osmosis is important for moving water from cell to cell, for example in plant roots. You will find out more about osmosis in Chapter 11.

KEY POINT

Osmosis in cells is the net movement of water from a dilute solution to a more concentrated solution across the partially permeable cell membrane.

SPECIALISED EXCHANGE SURFACES

All cells exchange substances with their surroundings, but some parts of animals or plants are specially adapted for the exchange of materials because they have a very large surface area in proportion to their volume. In animals, two examples are the alveoli (air sacs) of the lungs (Chapter 3) and the villi of the small intestine (Chapter 4). Diffusion is a slow process, and organs that rely on diffusion need a large surface over which it can take place. The alveoli allow the exchange of oxygen and carbon dioxide to take place between the air and the blood during breathing. The villi of the small intestine provide a large surface area for the absorption of digested food. In plants, exchange surfaces are also adapted by having a large surface area, such as the spongy mesophyll of the leaf (Chapter 10) and the **root hairs**.

KEY POINT

'Adapted' or 'an **adaptation**' means that the structure of a cell or an organism is suited to its function. It is a word that is very commonly used in biology, and will appear again in many of the chapters of this book. We also use it when we say that organisms are adapted to their environment.

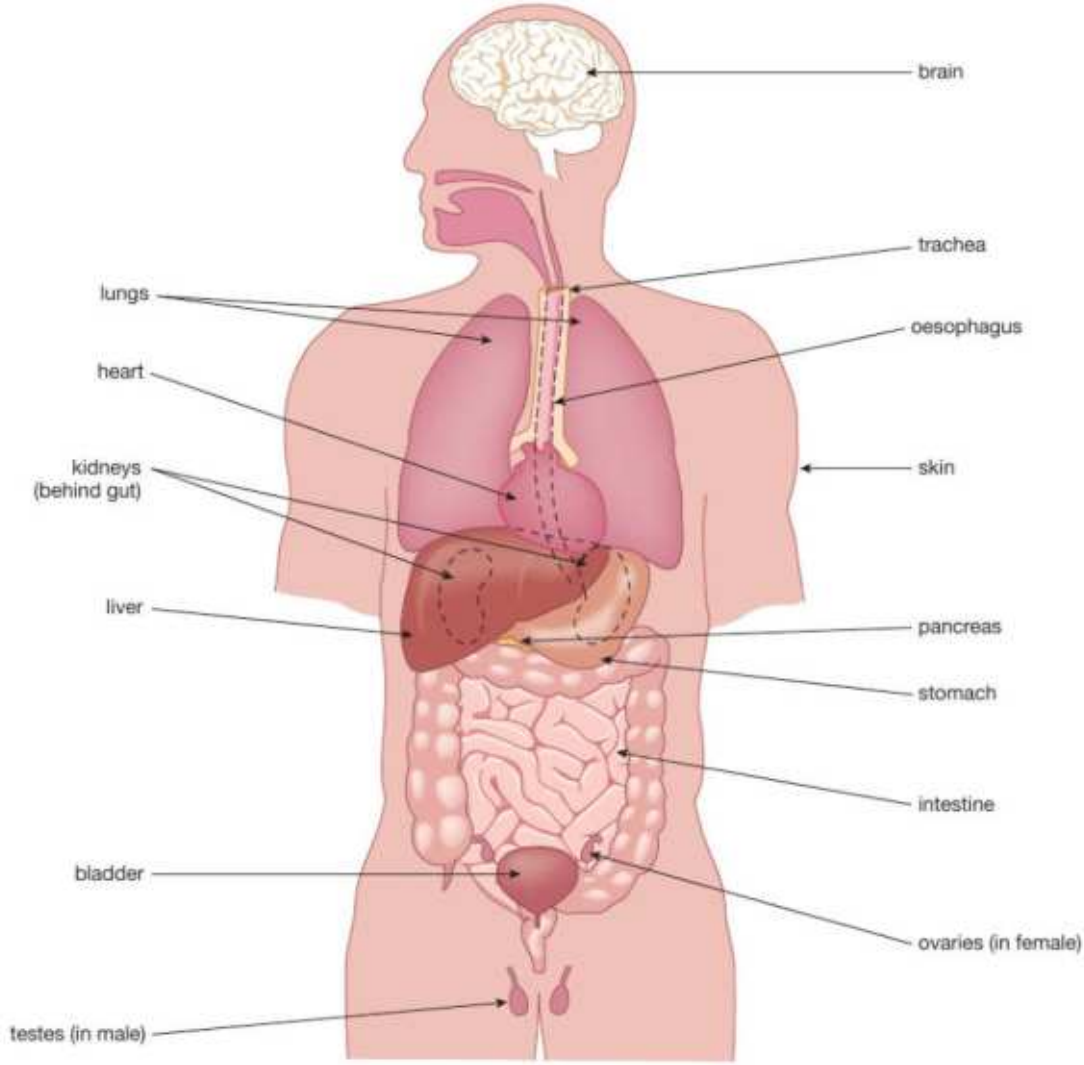
CELLS, TISSUES AND ORGANS

Cells with a similar function are grouped together as **tissues**. For example, the muscle of your arm contains millions of similar muscle cells, all specialised for one function – contraction to move the arm bones. This is muscle tissue. However, a muscle also contains other tissues, such as blood, nervous tissue and epithelium (lining tissue). A collection of several tissues carrying out a particular function is called an **organ**. The main organs of the human body are shown in Figure 1.14. Plants also have tissues and organs. Leaves, roots, stems and flowers are all plant organs.

In animals, jobs are usually carried out by several different organs working together. This is called an **organ system**. For example, the digestive system consists of the gut, along with glands such as the pancreas and gall bladder.

The function of the whole system is to digest food and absorb the digested products into the blood. There are seven main systems in the human body. These are the:

- digestive system
- gas exchange system – including the lungs, which exchange oxygen and carbon dioxide
- circulatory system – including the heart and blood vessels, which transport materials around the body
- excretory system – including the kidneys, which filter toxic waste materials from the blood
- nervous system – consisting of the brain, spinal cord and nerves, which coordinate the body's actions
- endocrine system – glands secreting hormones, which act as chemical messengers
- reproductive system – producing sperm in males and eggs in females, and allowing the development of the embryo.



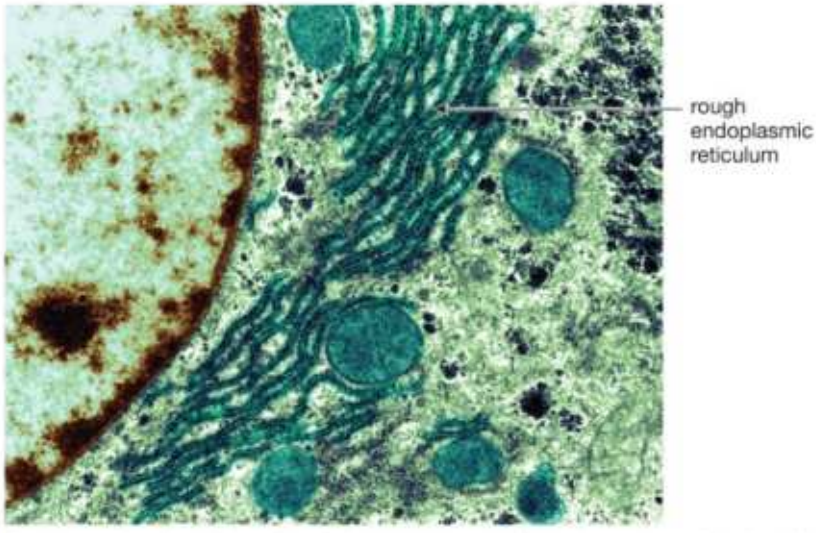
▲ Figure 1.14 Some of the main organs of the human body.

LOOKING AHEAD – MEMBRANES IN CELLS

If you continue to study biology beyond International GCSE, you will learn more about the structure and function of cells. You might like to look on the Internet for some electron micrographs and carry out some further research into cells.

Electron micrographs allow us to see cells at a much greater magnification than by using a light microscope. They also reveal more detail. The image produced by a light microscope can only distinguish features about the size of a mitochondrion. The electron microscope has a much greater *resolution*. Resolution is the ability to distinguish two points in an image as being separate. The maximum resolution of a light microscope is about 200 nanometres (nm), while with an electron microscope we can distinguish structures less than 1 nm in size. That is why ribosomes are only visible using an electron microscope – they are about 25 nm in diameter. A nanometre (nm) is 10^{-9} m, or one millionth of a milimetre.

Electron microscopy reveals that much of the cytoplasm is made up of membranes. As well as the cell surface membrane, there are membranes around organelles such as the nucleus, mitochondria and chloroplasts. In addition, there is an extensive system of membranes running throughout the cytoplasm, called the endoplasmic reticulum (ER). Some ER is covered in ribosomes, and is called rough ER (Figure 1.15).



▲ Figure 1.15 Rough endoplasmic reticulum is a system of membranes extending throughout the cytoplasm of a cell. It is covered with ribosomes the (tiny dots). Ribosomes are the site of protein synthesis.

There are thousands of different chemical reactions that take place inside cells. A key function of a cell membrane is to separate cell functions into different compartments so they don't take place together. For example, the reactions and enzymes of aerobic respiration are kept inside the mitochondria, separate from the rest of the cytoplasm.

CHAPTER QUESTIONS

More questions on life processes can be found at the end of Unit 1 on page 29.

SKILLS CRITICAL THINKING

1 Which of the following comparisons of animal and plant cells is *not* true?

	Animal cells	Plant cells
A	do not have chloroplasts	have chloroplasts
B	have mitochondria	do not have mitochondria
C	have temporary vacuoles	have permanent vacuoles
D	do not have cellulose cell walls	have cellulose cell walls

2 Which of the following descriptions is correct?

A The cell wall is freely permeable and the cell membrane is partially permeable

B The cell wall is partially permeable and the cell membrane is freely permeable

C Both the cell wall and the cell membrane are freely permeable

D Both the cell wall and the cell membrane are partially permeable

3 What are the products of anaerobic respiration in yeast?

A ethanol and carbon dioxide **B** lactate and carbon dioxide

C carbon dioxide and water **D** ethanol and water

SKILLS INTERPRETATION

4 a Draw a diagram of a plant cell. Label all of the parts. Alongside each label write the function of that part.

SKILLS CRITICAL THINKING

b Write down three differences between the cell you have drawn and a 'typical' animal cell.

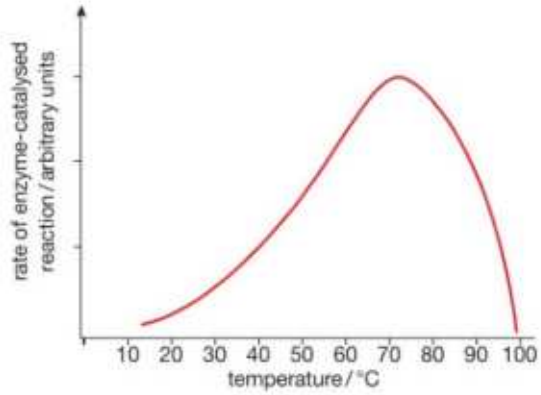
5 Write a short description of the nature and function of enzymes. Include in your description:

- a definition of an enzyme
- a description of the 'lock and key' model of enzyme action
- an explanation of the difference between intracellular and extracellular enzymes.

Your description should be about a page in length, including a labelled diagram.

SKILLS ANALYSIS

6 The graph shows the effect of temperature on an enzyme. The enzyme was extracted from microorganism that lives in hot mineral springs near a volcano.



a What is the optimum temperature of this enzyme?

b Explain why the activity of the enzyme is greater at 60 °C than at 30 °C.

c The optimum temperature of enzymes in the human body is about 37 °C. Explain why this enzyme is different.

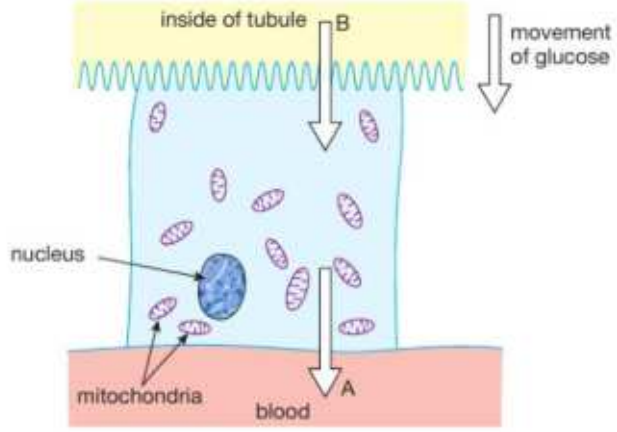
d What happens to the enzyme at 90 °C?

SKILLS INTERPRETATION

7 Explain the differences between diffusion and active transport.

SKILLS CRITICAL THINKING, INTERPRETATION

8 The diagram shows a cell from the lining of a human kidney tubule. A major role of the cell is to absorb glucose from the fluid passing along the tubule and pass it into the blood, as shown by the arrow on the diagram.



SKILLS ANALYSIS, INTERPRETATION

a What is the function of the mitochondria?

b The tubule cell contains a large number of mitochondria. They are needed for the cell to transport glucose across the cell membrane into the blood at 'A'. Suggest the method that the cell uses to do this and explain your answer.

c The mitochondria are *not* needed to transport the glucose into the cell from the tubule at 'B'. Name the process by which the ions move across the membrane at 'B' and explain your answer.

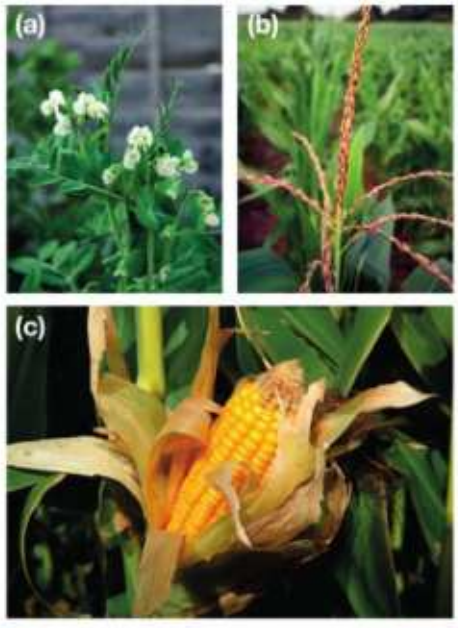
d The surface membrane of the tubule cell at 'B' is greatly folded. Suggest how this adaptation helps the cell to carry out its function.

2 THE VARIETY OF LIVING ORGANISMS

There is an enormous variety of living organisms. Biologists put them into groups according to their structure and function. The members of each group have certain features in common.

LEARNING OBJECTIVES

- Understand the difference between eukaryotic and prokaryotic organisms
- Describe the features common to plants and recognise examples of flowering plants such as maize, peas and beans
- Describe the features common to animals and recognise examples such as mammals and insects
- Describe the features common to fungi and recognise examples such as *Mucor* and yeast
- Describe the features common to protoctists and recognise examples such as *Amoeba*, *Chlorella* and *Plasmodium*
- Describe the features common to bacteria and recognise examples such as *Lactobacillus bulgaricus* and *Pneumococcus*
- Describe the features common to viruses and recognise examples such as the influenza virus, the HIV virus and the tobacco mosaic virus
- Understand the term 'pathogen' and know that pathogens may include fungi, bacteria, protoctists or viruses.



▲ Figure 2.1 (a) A pea plant. Its leaves and stem cells contain chloroplasts, giving them their green colour. The white flowers are pollinated by insects. (b) Maize plants are pollinated by wind. These are the male flowers, which make the pollen. (c) The female maize flowers produce seeds after pollination.

There are more than ten million species of organisms alive on Earth today, and many more that once lived on Earth but are now extinct. In order to make sense of this enormous variety biologists classify organisms, putting them into groups. Members of each group are related – they are descended from a common ancestor by the process of evolution (see Chapter 19). This common ancestry is reflected in the similarities of structure and function of the members of a group.

The five major groups of living organisms are plants, animals, fungi, protoctists and bacteria.

PLANTS

You will be familiar with flowering plants, such as those shown in Figure 2.1. This group, or **kingdom**, also contains simpler plants, such as mosses and ferns. All plants are multicellular, which means that their 'bodies' are made up of many cells. Their main distinguishing feature is that their cells contain chloroplasts and they carry out photosynthesis – the process that uses light energy to convert simple inorganic molecules such as water and carbon dioxide into complex organic compounds (see Chapter 10). One of these organic compounds is the carbohydrate cellulose, and all plants have cell walls made of this material.

Plants can make many other organic compounds as a result of photosynthesis. One of the first to be made is the storage carbohydrate **starch**, which is often found inside plant cells. Another is the sugar **sucrose**, which is transported around the plant and is sometimes stored in fruits and other plant organs. The structure and function of flowering plants is dealt with in Unit 3 of this book.

ANIMALS

You will be even more familiar with this kingdom, since it contains the species *Homo sapiens*, i.e. humans! The variety of the animal kingdom is also enormous, including organisms such as sponges, molluscs, worms, starfish, insects and crustaceans, through to larger animals such as fish, amphibians, reptiles, birds and mammals (Figure 2.2). The last five groups are all **vertebrates**, which means that they have a vertebral column, or backbone. All other animals lack this feature, and are called **invertebrates**.

(a) (b) (c)



▲ Figure 2.2 (a) A housefly. (b) A mosquito, feeding on human blood. Houseflies and mosquitoes are both insects, which make up the largest sub-group of all the animals. About 60% of all animal species are insects. (c) This high jumper's movement is coordinated by a complex nervous system.

Animals are also multicellular organisms. Their cells never contain chloroplasts, so they are unable to carry out photosynthesis. Instead, they gain their nutrition by feeding on other animals or plants. Animal cells also lack cell walls, which allows their cells to change shape, an important feature for organisms that need to move from place to place. Movement in animals is achieved in various ways, but often involves coordination by a nervous system (see Chapter 6). Another feature common to most animals is that they store carbohydrate in their cells as a compound called **glycogen** (see Chapter 4). The structure and function of animals is dealt with in Unit 2 of this book.

FUNGI

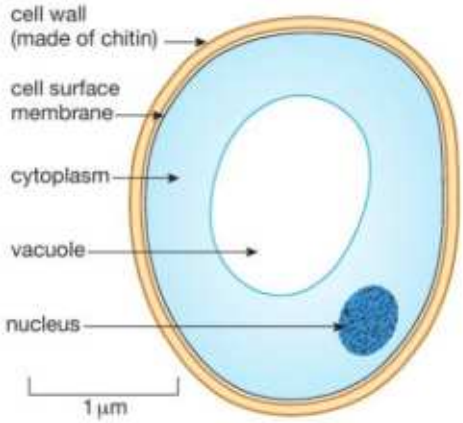
Fungi include mushrooms and toadstools, as well as moulds. These groups of fungi are multicellular. Another group of fungi is the yeasts, which are **unicellular** (made of single cells). Different species of yeasts live everywhere – on the surface of fruits, in soil, water, and even on dust in the air. The yeast powder used for baking contains millions of yeast cells (Figure 2.3). The cells of fungi never contain chloroplasts, so they cannot photosynthesise. Their cells have cell walls, but they are not composed of cellulose (Figure 2.4).

EXTENSION WORK

Because fungi have cell walls, they were once thought to be plants that had lost their chlorophyll. We now know that their cell wall is not made of cellulose as in plants, but of a different chemical called **chitin** (the same material that makes up the outside skeleton of insects). There are many ways that fungi are very different from plants (the most obvious is that fungi do not photosynthesise) and they are not closely related to plants at all.



▲ Figure 2.3 Yeast cells, highly magnified



▲ Figure 2.4 Structure of a yeast cell

KEY POINT

The singular of hyphae is hypha.



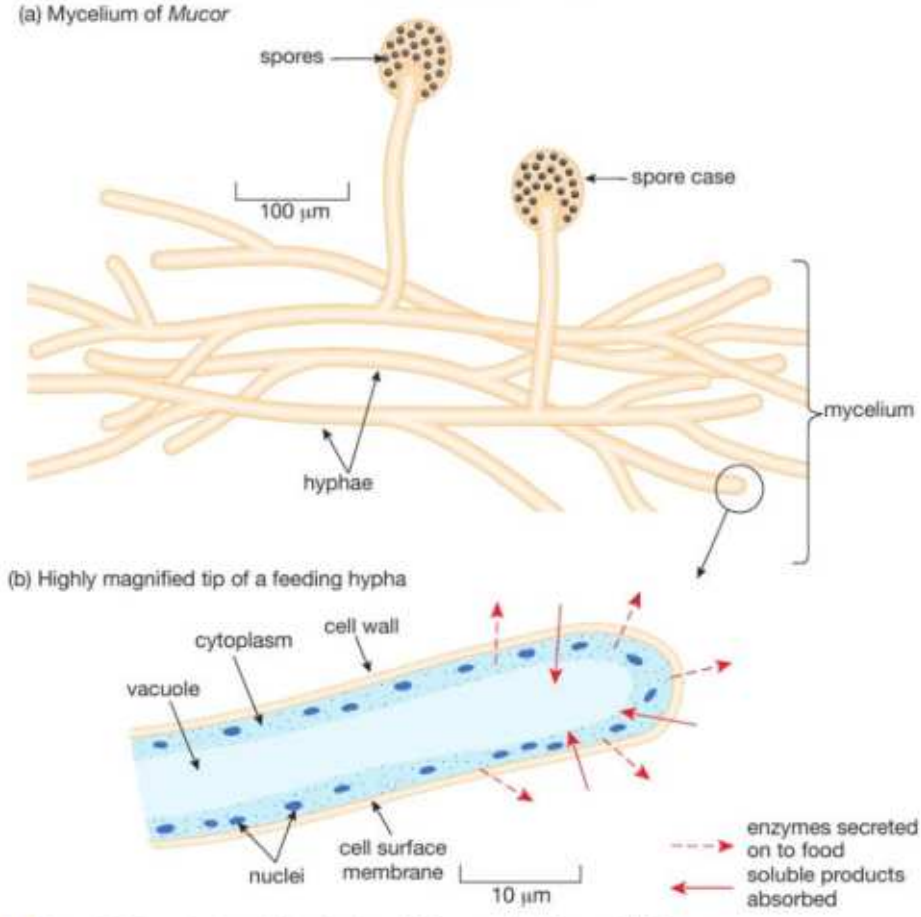
▲ Figure 2.5 Toadstools growing on a rotting tree trunk



▲ Figure 2.6 The 'pin mould' *Mucor* growing on a piece of bread. The dark spots are structures that produce spores for reproduction.

A mushroom or toadstool is the reproductive structure of the organism, called a fruiting body (Figure 2.5). Under the soil, the mushroom has many fine thread-like filaments called **hyphae** (pronounced high-fee). A mould is rather like a mushroom without the fruiting body. It just consists of the network of hyphae (Figure 2.6). The whole network is called a **mycelium** (pronounced my-sea-lee-um). Moulds feed by absorbing nutrients from dead (or sometimes living) material, so they are found wherever this is present, for example, in soil, rotting leaves or decaying fruit.

If you leave a piece of bread or fruit exposed to the air for a few days, it will soon become mouldy. Mould spores carried in the air have landed on the food and grown into a mycelium of hyphae (Figure 2.7).



▲ Figure 2.7 The structure of a typical mould fungus, the 'pin mould' *Mucor*.

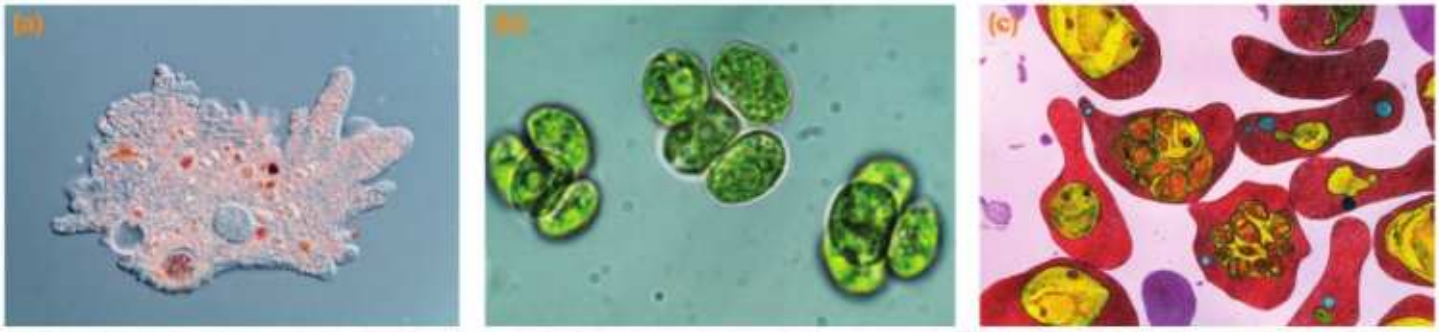
The thread-like hyphae of *Mucor* have cell walls surrounding their cytoplasm. The cytoplasm contains many nuclei. In other words the hyphae are not divided up into separate cells.

When a spore from *Mucor* lands on the food, a hypha grows out from it. The hypha grows and branches again and again, until the mycelium covers the surface of the food. The hyphae secrete digestive enzymes on to the food, breaking it down into soluble substances such as sugars, which are then absorbed by the mould. Eventually, the food is used up and the mould must infect another source of food by producing more spores.

When an organism feeds on dead organic material in this way, and digestion takes place outside of the organism, this is called **saprotrophic** nutrition. Enzymes that are secreted out of cells for this purpose are called *extracellular* enzymes (see Chapter 1).

PROTOCTISTS

Protoctists are sometimes called the 'dustbin kingdom', because they are a mixed group of organisms that don't fit into the plants, animals or fungi. Most protoctists are microscopic single-celled organisms (Figure 2.8). Some look like animal cells, such as *Amoeba*, which lives in pond water. These are known as **protozoa**. Other protoctists have chloroplasts and carry out photosynthesis, so are more like plants. These are called **algae**. Most algae are unicellular, but some species such as seaweeds are multicellular and can grow to a great size. Some protoctists are the agents of disease, such as *Plasmodium*, the organism that causes malaria.



▲ Figure 2.8 (a) *Amoeba*, a protozoan that lives in ponds (b) *Chlorella*, a unicellular freshwater alga (c) Blood cells containing the protoctist parasite *Plasmodium*, the organism responsible for causing malaria

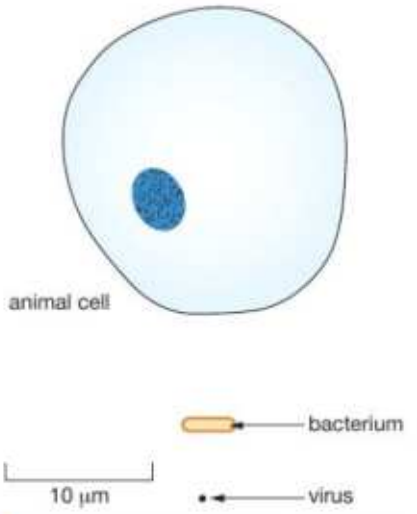
EUKARYOTIC AND PROKARYOTIC ORGANISMS

All the organisms described so far are composed of **eukaryotic** cells and are known as eukaryotic organisms. 'Eukaryotic' means 'having a nucleus' – their cells contain a nucleus surrounded by a membrane, along with other membrane bound organelles, such as mitochondria and chloroplasts.

There are also organisms made of simpler cells, which have no nucleus, mitochondria or chloroplasts. These are called **prokaryotic** cells. 'Prokaryotic' means 'before nucleus'. The main forms of prokaryotic organisms are the bacteria.

BACTERIA

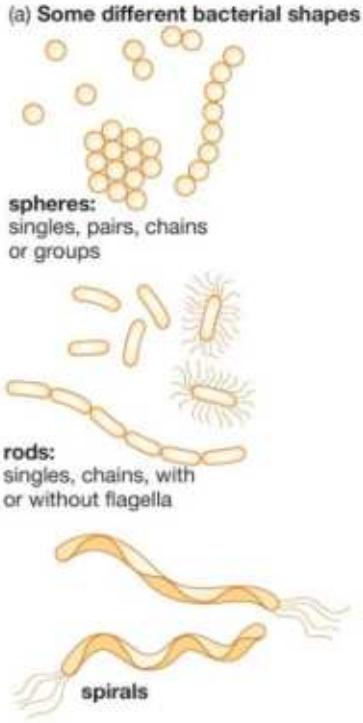
Bacteria are small single-celled organisms. Their cells are much smaller than those of eukaryotic organisms and have a much simpler structure. To give you some idea of their size, a typical animal cell might be 10 to 50 μm in diameter (1 μm, or one micrometre, is a millionth of a metre). Compared with this, a typical bacterium is only 1 to 5 μm in length (Figure 2.9) and its volume is thousands of times smaller than that of the animal cell.

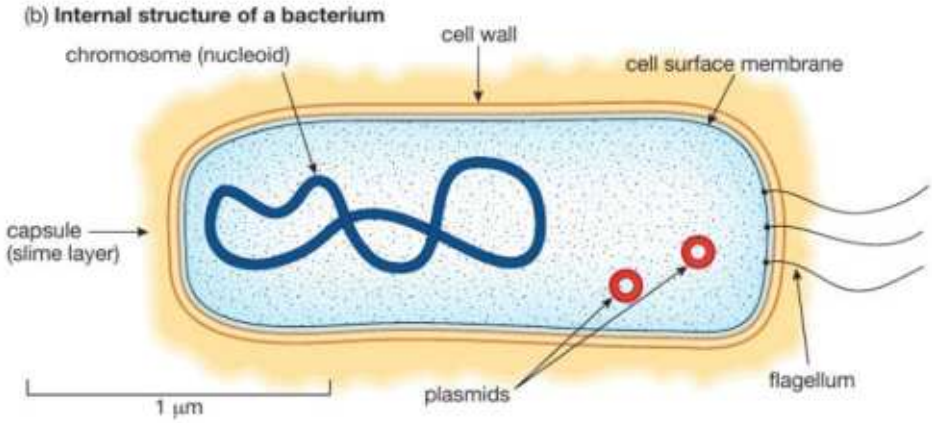


▲ Figure 2.9 A bacterium is much smaller than an animal cell. The relative size of a virus is also shown.

There are three basic shapes of bacteria: spheres, rods and spirals, but they all have a similar internal structure (Figure 2.10).

All bacteria are surrounded by a cell wall, which protects the bacterium and keeps the shape of the cell. Bacterial cell walls are not made of cellulose but a complex compound of sugars and proteins called peptidoglycan. Some species have another layer outside this wall, called a **capsule** or slime layer. Both give the bacterium extra protection. Underneath the cell wall is the cell membrane, as in other cells. The middle of the cell is made of cytoplasm. Since it is a prokaryotic cell, the bacterium has no nucleus. Instead, its genetic material (DNA) is in a single chromosome, loose in the cytoplasm, forming a circular loop.





◀▲ Figure 2.10 Structure of bacteria

Some bacteria can swim, and are propelled through water by corkscrew-like movements of structures called flagella (a single one of these is called a **flagellum**). However, many bacteria do not have flagella and cannot move by themselves. Other structures present in the cytoplasm include the **plasmids**. These are small circular rings of DNA, carrying some of the bacterium's genes. Not all bacteria contain plasmids, although about three-quarters of all known species do. Plasmids have very important uses in genetic engineering (see Chapter 21).

Some bacteria contain a form of chlorophyll in their cytoplasm, and can carry out photosynthesis. However, most bacteria feed off other living or dead organisms. Along with the fungi, many bacteria are important **decomposers** (see Chapter 14), recycling dead organisms and waste products in the soil and elsewhere. Some bacteria are used by humans to make food, such as *Lactobacillus bulgaricus*, a rod-shaped species used in the production of yoghurt from milk (Figure 2.11). Other species are **pathogens**, which means that they cause disease (Figure 2.12).

Despite the relatively simple structure of the bacterial cell, it is still a living cell that carries out the normal processes of life, such as respiration, feeding, excretion, growth and reproduction. As you have seen, some bacteria can move, and they can also respond to a range of stimuli. For example, they may move towards a source of food, or away from a poisonous chemical. You should think about these features when you compare bacteria with the next group, the much simpler viruses.

KEY POINT

'Pathogens are organisms that cause disease. Many common animal and plant diseases are caused by bacteria or viruses. Most protoctists are free-living, but a few species are pathogens, such as *Plasmodium* (Figure 2.8). Even some species of fungi can cause disease, e.g. the skin infection called 'athlete's foot' is caused by a mould.



▲ Figure 2.11 The bacterium *Lactobacillus bulgaricus*, used in the production of yoghurt.

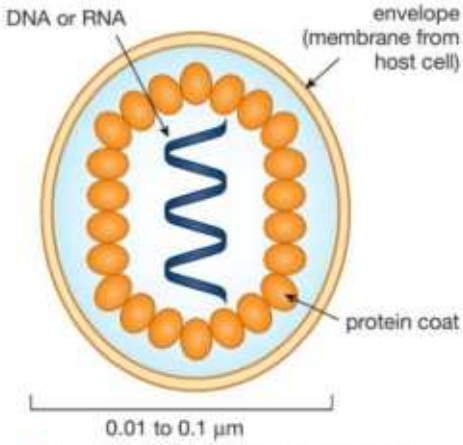


▲ Figure 2.12 Rounded cells of the bacterium *Pneumococcus*, one cause of pneumonia.

VIRUSES

All **viruses** are **parasites**, and can only reproduce inside living cells. The cell in which the virus lives is called the host. There are many different types of viruses. Some live in the cells of animals or plants, and there are even viruses which infect bacteria. Viruses are much smaller than bacterial cells: most are between 0.01 and 0.1 μm in diameter (Figure 2.9).

Viruses are not made of cells. A virus particle is very simple. It has no nucleus or cytoplasm, and is composed of a core of genetic material surrounded by a protein coat (Figure 2.13). The genetic material can be either **DNA**, or a similar chemical called **ribonucleic acid (RNA)**. In either case, the genetic material makes up just a few genes – all that is needed for the virus to reproduce inside its host cell.



▲ Figure 2.13 The structure of a typical virus, such as the type causing influenza (flu).

EXTENSION WORK

AIDS is not actually a disease but a 'syndrome'. A syndrome is a set of symptoms caused by a medical condition. In the case of HIV, the virus severely damages the person's immune system, so they are more likely to get other diseases, such as tuberculosis. They may also develop some unusual types of cancer. This collection of different symptoms is referred to as AIDS.



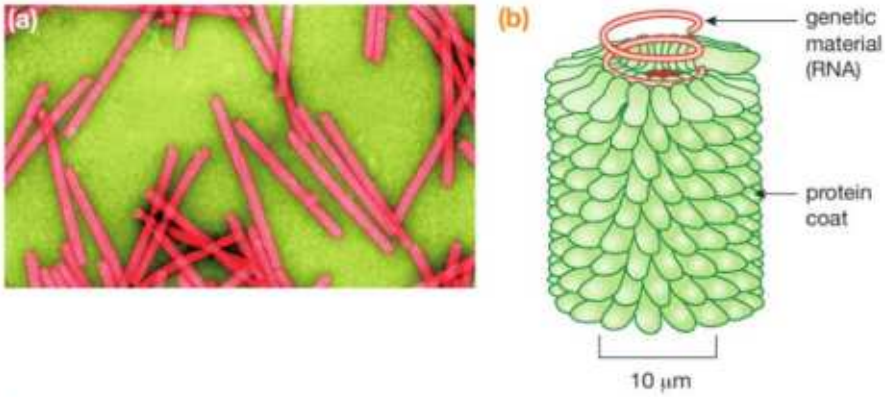
▲ Figure 2.15 Discolouration of the leaves of a tobacco plant, caused by infection with tobacco mosaic virus.

Sometimes a membrane called an envelope may surround a virus particle, but the virus does not make this. Instead it is 'stolen' from the surface membrane of the host cell.

Viruses do not feed, respire, excrete, move, grow or respond to their surroundings. They do not carry out any of the normal 'characteristics' of living things except reproduction, and they can only do this parasitically. This is why biologists do not consider viruses to be living organisms. You can think of them as being on the border between an organism and a non-living chemical.

A virus reproduces by entering the host cell and taking over the host's genetic machinery to make more virus particles. After many virus particles have been made, the host cell dies and the particles are released to infect more cells. Many human diseases are caused in this way, such as influenza ('flu'). Other examples include colds, measles, mumps, polio and rubella ('German measles'). Of course, the reproduction process does not continue forever. Usually, the body's immune system destroys the virus and the person recovers. Sometimes, however, a virus cannot be destroyed by the immune system quickly enough, and it may cause permanent damage or death. With other infections, the virus may attack cells of the immune system itself. This is the case with HIV (the Human Immunodeficiency Virus), which causes the illness called AIDS (Acquired Immune Deficiency Syndrome).

Viruses don't just parasitise animal cells. Some infect plant cells, such as the tobacco mosaic virus (Figure 2.14), which interferes with the ability of the tobacco plant to make chloroplasts, causing mottled patches to develop on the leaves (Figure 2.15).



▲ Figure 2.14 (a) Tobacco mosaic virus (TMV), seen through an electron microscope. (b) Structure of part of a TMV particle, magnified 1.25 million times.

CHAPTER QUESTIONS

More questions on the variety of living organisms can be found at the end of Unit 1 on page 29.

SKILLS CRITICAL THINKING

1 Which of the following is *not* a characteristic of plants?

A cells contain chloroplasts

B cell wall made of cellulose

C bodies are multicellular

D store carbohydrate as glycogen

SKILLS CRITICAL THINKING

2 Fungi carry out *saprotrophic nutrition*. What is the meaning of this term?

A extracellular digestion of dead organic matter
B feeding on other living organisms
C making organic molecules by photosynthesis
D secreting digestive enzymes

3 Below are three groups of organisms.

1. viruses
2. bacteria
3. yeasts

Which of these organisms are prokaryotic?

A 1 only
B 2 only
C 1 and 2
D 1, 2 and 3

4 Which of the following diseases is *not* caused by a virus?

A influenza
B measles
C malaria
D AIDS

5 a Name the kingdom to which each of the following organisms belongs:

i mushroom

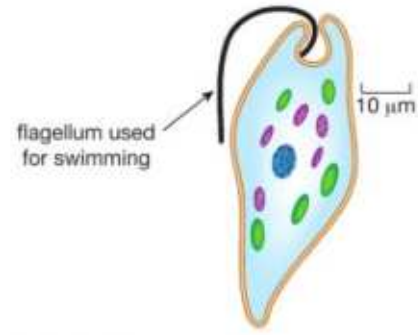
ii *Chlorella*

iii moss

iv *Lactobacillus*

SKILLS ANALYSIS, REASONING

b The diagram shows a species of protoctist called *Euglena*. Use the diagram to explain why *Euglena* is classified as a protoctist and not as an animal or plant.



SKILLS INTERPRETATION

6 a Draw a diagram to show the structure of a typical virus particle.

SKILLS CRITICAL THINKING

b Is a virus a living organism? Explain your answer.

c Explain the statement 'viruses are all parasites'.

7 Explain the meanings of the following terms:

a invertebrate

b hyphae

c saprotrophic

UNIT QUESTIONS

SKILLS CRITICAL THINKING 5th

1 These three organelles are found in cells: nucleus, chloroplast and mitochondrion.

a Which of the above organelles would be found in:

i a cell from a human muscle? **(1)**

ii a palisade cell from a leaf? **(1)**

iii a cell from the root of a plant? **(1)**

SKILLS REASONING

b Explain fully why the answers to ii) and iii) above are different. **(1)**

SKILLS INTERPRETATION

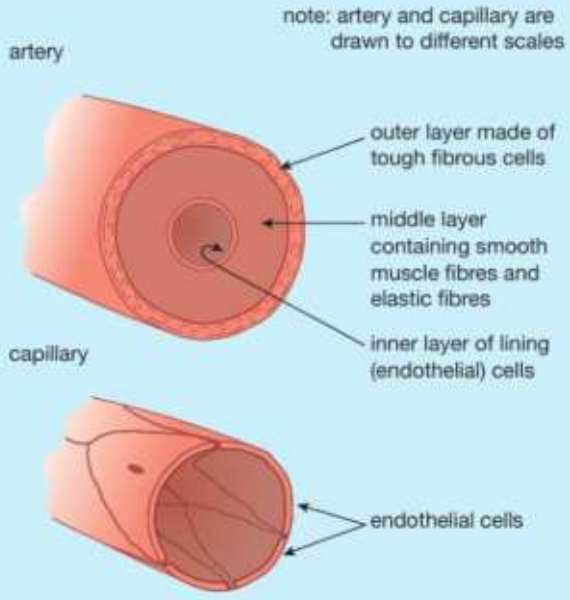
c What is the function of each organelle? **(3)**

(Total 7 marks)

SKILLS INTERPRETATION, REASONING

2 In multicellular organisms, cells are organised into tissues, organs and organ systems.

a The diagram shows a section through an artery and a capillary.



Explain why an artery can be considered to be an organ whereas a capillary cannot. **(2)**

b Organ systems contain two or more organs whose functions are linked. The digestive system is one human organ system. (See Chapter 4.)

SKILLS CRITICAL THINKING 4th

i What does the digestive system do? **(2)**

5th

ii Name three organs in the human digestive system. Explain what each organ does as part of the digestive system. **(6)**

4th

iii Name two other human organ systems and, for each system, name two organs that are part of the system. **(6)**

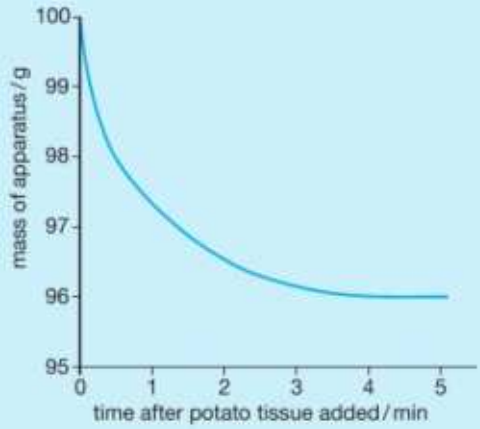
(Total 16 marks)

SKILLS ANALYSIS

3 Catalase is an enzyme found in many plant and animal cells. It catalyses the breakdown of hydrogen peroxide into water and oxygen.

$$\text{hydrogen peroxide} \xrightarrow{\textit{catalase}} \text{water} + \text{oxygen}$$

a In an investigation into the action of catalase in potato, 20 g of potato tissue was put into a small beaker containing hydrogen peroxide weighing 80 g in total. The temperature was maintained at 20 °C throughout the investigation. As soon as the potato was added, the mass of the beaker and its contents was recorded until there was no further change in mass. The results are shown in the graph.



i How much oxygen was formed in this investigation? Explain your answer. **(2)**

ii Estimate the time by which half this mass of oxygen had been formed. **(2)**

SKILLS REASONING

iii Explain, in terms of collisions between enzyme and substrate molecules, why the rate of reaction changes during the course of the investigation. **(2)**

b The students repeated the investigation at 30 °C. What difference, if any, would you expect in:

SKILLS DECISION MAKING

i the mass of oxygen formed?

ii the time taken to form this mass of oxygen?

Explain your answers. **(4)**

(Total 10 marks)

CRITICAL THINKING

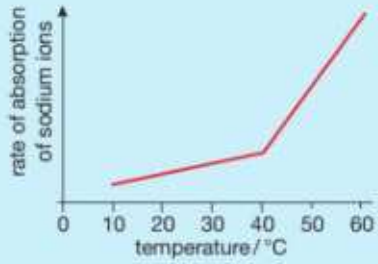
4 Different particles move across cell membranes using different processes.

a The table below shows some ways in which active transport, osmosis and diffusion are similar and some ways in which they are different. Copy and complete the table with ticks and crosses. **(3)**

Feature	Active transport	Osmosis	Diffusion
particles must have kinetic energy			
requires energy from respiration			
particles move down a concentration gradient			

SKILLS CRITICAL THINKING

b The graph shows the results of an investigation into the rate of diffusion of sodium ions across the membranes of potato cells.



SKILLS ANALYSIS, REASONING

i Explain the increase in the rate of diffusion up to 40 °C. **(2)**

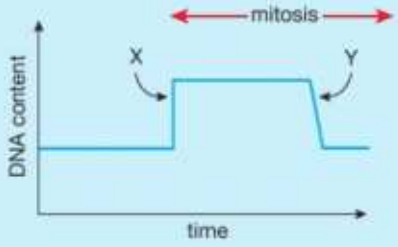
ii Suggest why the rate of increase is much steeper at temperatures above 40 °C. **(2)**

(Total 7 marks)

SKILLS REASONING

5 Cells in the wall of the small intestine divide by mitosis to replace cells lost as food passes through.

a Chromosomes contain DNA. The graph shows the changes in the DNA content of a cell in the wall of the small intestine as it divides by mitosis.

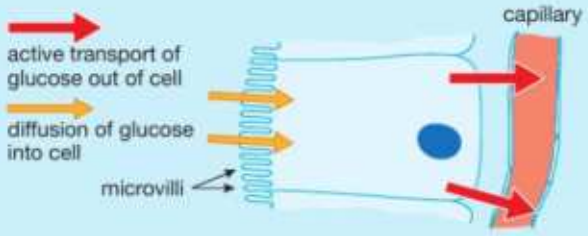


i Why is it essential that the DNA content is doubled (X) before mitosis begins? **(2)**

SKILLS ANALYSIS

ii What do you think happens to the cell at point Y? **(1)**

b The diagram shows a cell in the wall of a villus in the small intestine. Some of the processes involved in the absorption of glucose are also shown.



SKILLS INTERPRETATION

i What is the importance of the small intestine having villi? **(1)**

ii Suggest how the microvilli adapt this cell to its function of absorbing glucose. **(1)**

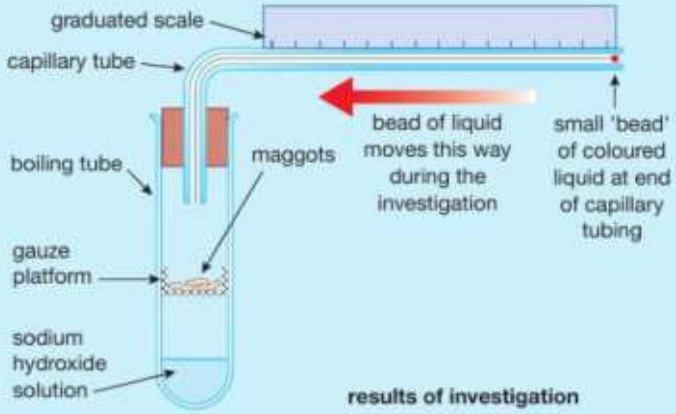
iii Suggest how the active transport of glucose out of the cell and into the blood stream helps with the absorption of glucose from the small intestine. **(2)**

(Total 7 marks)

SKILLS REASONING 6

A respirometer is used to measure the rate of respiration. The diagram shows a simple respirometer. The sodium hydroxide solution in the apparatus absorbs carbon dioxide. Some results from the investigation are also shown.

Safety note: Eye protection should be worn when setting up the apparatus as sodium hydroxide is very hazardous to the eyes.



results of investigation

Experiment	Distance moved by bead / mm
1	20
2	3
3	18

Assume that the maggots in the apparatus respire aerobically.

a Write the symbol equation for aerobic respiration. (4)

b From the equation, what can you assume about the amount of oxygen taken in and carbon dioxide given off by the maggots? Explain your answer. (3)

c Result 2 is significantly different from the other two results. Suggest a reason for this. (2)

d How would the results be different if the organisms under investigation respired anaerobically? **(2)**

(Total 11 marks)

SKILLS INTERPRETATION 7

The table below shows some features of different groups of organisms. Copy and complete the table by putting a tick in the box if the organism has that feature, or a cross if it lacks the feature.

Feature	Type of organism		
	Plant	Fungus	Virus
they are all parasites			
they are made up of a mycelium of hyphae			
they can only reproduce inside living cells			
they feed by extracellular digestion by enzymes			
they store carbohydrate as starch			

(Total 5 marks)

SKILLS CRITICAL THINKING

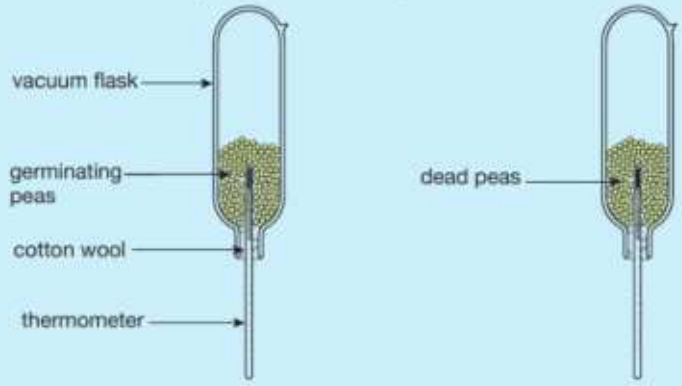
8 Copy and complete the following account.

Plants have cell walls made of _____ . They store carbohydrate as the insoluble compound called _____ or sometimes as the sugar _____ . Plants make these substances as a result of the process called _____ . Animals, on the other hand, store carbohydrate as the compound _____ . Both animals' and plants' cells have nuclei, but the cells of bacteria lack a true nucleus, having their DNA in a circular chromosome. They sometimes also contain small rings of DNA called _____ , which are used in genetic engineering. Bacteria and fungi break down organic matter in the soil. They are known as _____ . Some bacteria are pathogens, which means that they _____ .

(Total 8 marks)

SKILLS DECISION MAKING

9 The diagram shows the apparatus used to investigate germination of pea seeds. At the start of the experiment the temperature in both flasks was 19 °C



The apparatus was left for 24 hours. At the end of this time the temperature in the flask with germinating peas was 22 °C, while the temperature in the flask with dead peas was 19 °C.

a Explain the biological reason for this difference in temperature. **(2)**

b The seeds in both flasks were washed in disinfectant before the experiment. Explain why this was done. **(1)**

c Cotton wool was used to hold the seeds in the flasks. Suggest why cotton wool was used instead of a rubber bung. **(1)**

SKILLS EXECUTIVE FUNCTION

d Pea seeds were used in both flasks. State another variable that should have been controlled in the experiment. **(1)**

(Total 5 marks)

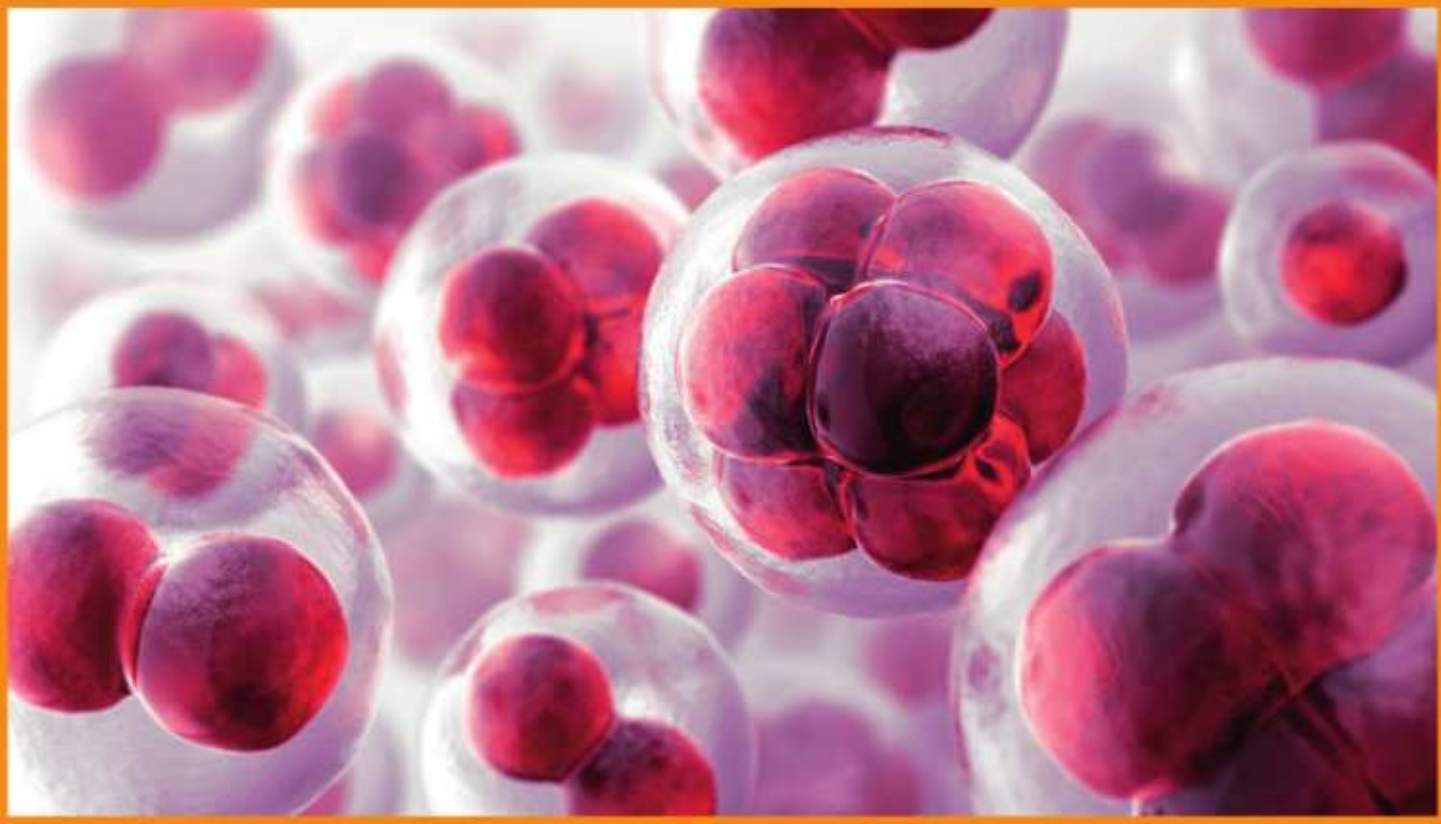
10 A piece of meat is a tissue composed of muscle fibres. Muscle fibres use ATP when they contract. Describe an investigation to find out if a solution of ATP will cause the contraction of muscle fibres.

(Total 6 marks)

BREATHING AND GAS EXCHANGE 35
FOOD AND DIGESTION 48
BLOOD AND CIRCULATION 64
COORDINATION 77
CHEMICAL COORDINATION 91
HOMEOSTASIS AND EXCRETION 97
REPRODUCTION IN HUMANS 104

BIOLOGY UNIT 2 ANIMAL PHYSIOLOGY

Physiology is the branch of biology that looks at how living things function. It studies the workings of an organism at different levels from cells, tissues and organs through to the whole organism. In this unit we look at animal physiology and in particular how the human body works. It is important to study physiology, not least because knowledge of the body is essential in understanding how to treat it when it goes wrong. This is reflected in the fact that one of the six categories of Nobel Prize is awarded for 'physiology or medicine'.



3 BREATHING AND GAS EXCHANGE

When we breathe, air is moved in and out of the lungs so that gas exchange can take place between the air and the blood. This chapter looks at these processes, and also deals with some ways that smoking can damage the lungs and stop these vital organs from working properly.

LEARNING OBJECTIVES

- Describe the structure of the thorax, including the ribs, intercostal muscles, diaphragm, trachea, bronchi, bronchioles, alveoli and pleural membranes
- Understand the role of the intercostal muscles and the diaphragm in ventilation
- Explain how alveoli are adapted for gas exchange by diffusion between air in the lungs and blood in capillaries
- Investigate breathing in humans, including the release of carbon dioxide and the effect of exercise
- Understand the biological consequences of smoking in relation to the lungs and circulatory system, including coronary heart disease.

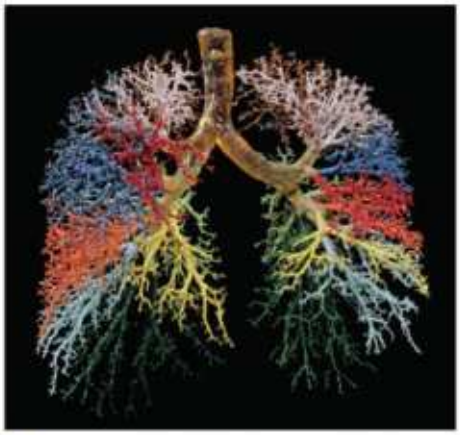
Cells get their energy by oxidising foods such as glucose, during the process called **respiration**. If cells are to respire aerobically, they need a continuous supply of oxygen from the blood. In addition, carbon dioxide from respiration needs to be removed from the body. In humans, these gases are exchanged between the blood and the air in the lungs.

RESPIRATION AND BREATHING

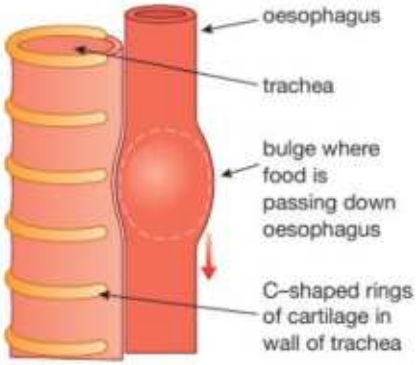
You need to understand the difference between respiration and breathing. Respiration is the oxidation reaction that releases energy from foods such as glucose (Chapter 1). Breathing is the mechanism that moves air into and out of the lungs, allowing gas exchange to take place. The lungs and associated structures are often called the 'respiratory system' but this can be confusing. It is better to call them the gas exchange system and this is the term we use in this book.

THE STRUCTURE OF THE GAS EXCHANGE SYSTEM

The lungs are enclosed in the chest or **thorax** by the ribcage and a muscular sheet of tissue called the **diaphragm** (Figure 3.1). As you will see, the actions of these two structures bring about the movements of air into and out of the lungs. Joining each rib to the next are two sets of muscles called **intercostal muscles** ('costals' are rib bones). The diaphragm separates the contents of the thorax from the abdomen. It is not flat, but a shallow dome shape, with a fibrous middle part forming the 'roof' of the dome, and muscular edges forming the walls.



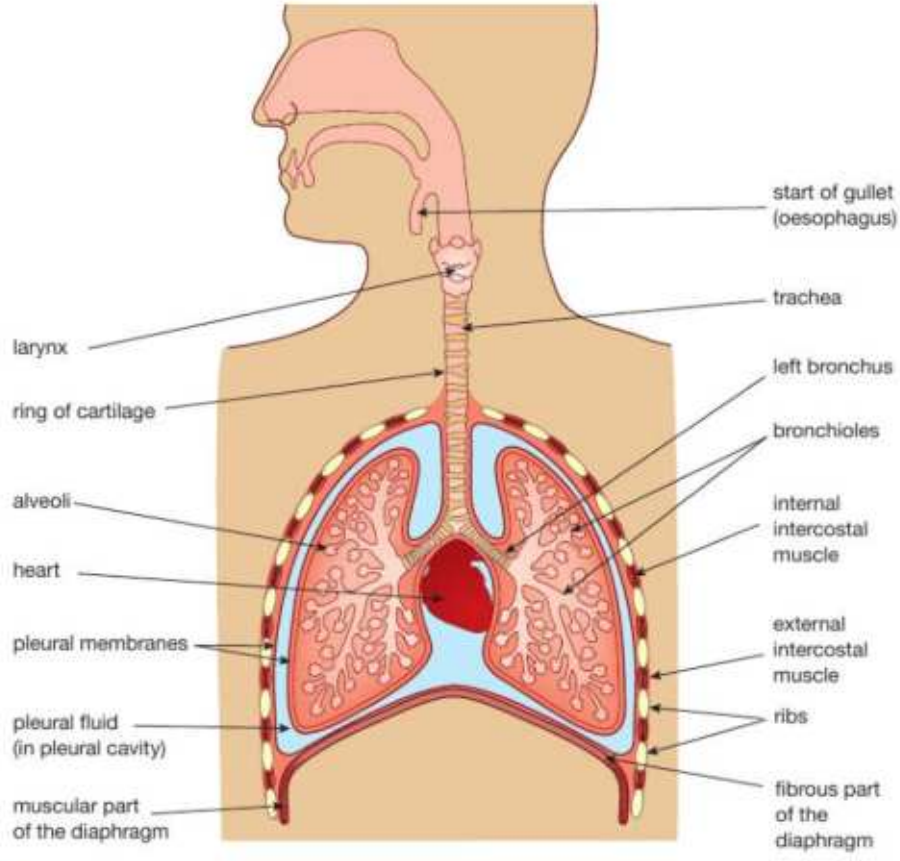
▲ Figure 3.2 This cast of the human lungs was made by injecting a pair of lungs with a liquid plastic. The plastic was allowed to set, then the lung tissue was dissolved away with acid.



▲ Figure 3.3 C-shaped cartilage rings in the trachea.

EXTENSION WORK

In the bronchi, the cartilage forms complete, circular rings. In the trachea, the rings are incomplete, and shaped like a letter 'C'. The open part of the ring is at the back of the trachea, next to where the oesophagus (gullet) lies as it passes through the thorax. When food passes along the oesophagus by peristalsis (see Chapter 4) the gaps in the rings allow the lumps of food to pass through more easily, without the peristaltic wave 'catching' on the rings (Figure 3.3).



▲ Figure 3.1 The human gas exchange system

The air passages of the lungs form a highly branching network (Figure 3.2). This is why it is sometimes called the **bronchial tree**.

When we breathe in, air enters our nose or mouth and passes down the windpipe or **trachea**. The trachea splits into two tubes called the **bronchi** (singular **bronchus**), one leading to each lung. Each bronchus divides into smaller and smaller tubes called **bronchioles**, eventually ending at microscopic air sacs, called **alveoli** (singular **alveolus**). It is here that gas exchange with the blood takes place.

The walls of trachea and bronchi contain rings of gristle or **cartilage**. These support the airways and keep them open when we breathe in. They are rather like the rings in a vacuum cleaner hose – without them the hose would squash flat when the cleaner sucks air in.

The inside of the thorax is separated from the lungs by two thin, moist membranes called the **pleural membranes**. They make up a continuous envelope around the lungs, forming an airtight seal. Between the two membranes is a space called the **pleural cavity**, filled with a thin layer of liquid called **pleural fluid**. This acts as lubrication, so that the surfaces of the lungs don't stick to the inside of the chest wall when we breathe.

KEEPING THE AIRWAYS CLEAN

The trachea and larger airways are lined with a layer of cells that have an important role in keeping the airways clean. Some cells in this lining secrete a sticky liquid called **mucus**, which traps particles of dirt or bacteria that are breathed in. Other cells are covered with tiny hair-like structures called **cilia** (Figure 3.4). The cilia beat backward and forward, sweeping the mucus and trapped particles out towards the mouth. In this way, dirt and bacteria are



▲ Figure 3.4 This electron microscope picture shows cilia from the lining of the trachea.

prevented from entering the lungs, where they might cause an infection. As you will see, one of the effects of smoking is that it destroys the cilia and stops this protection mechanism from working properly.

VENTILATION OF THE LUNGS

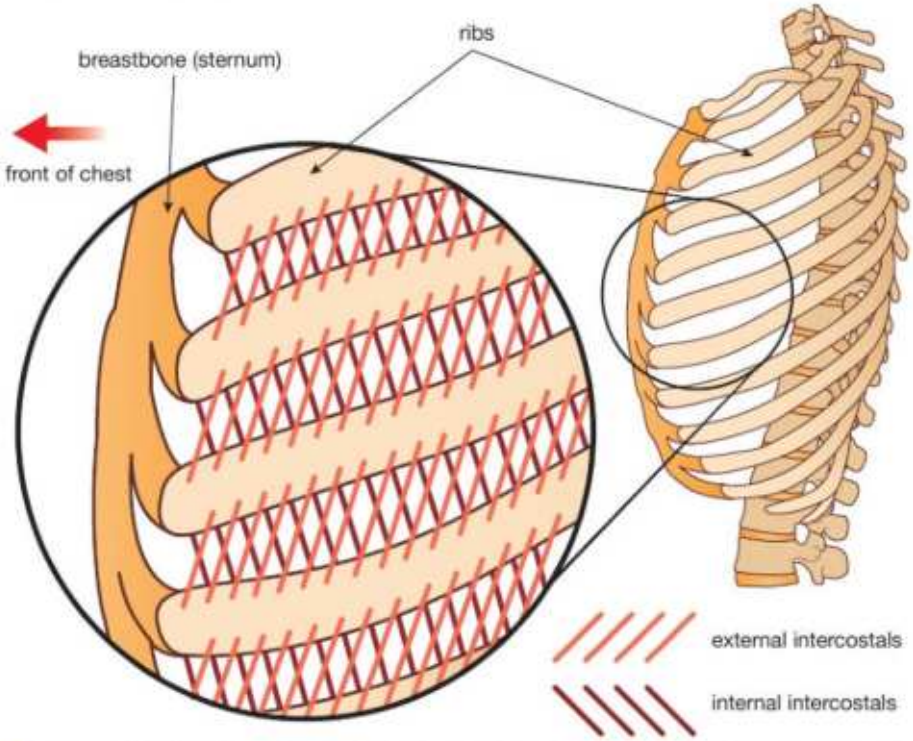
Ventilation means moving air in and out of the lungs. This requires a difference in air pressure – the air moves from a place where the pressure is high to one where it is low. Ventilation depends on the fact that the thorax is an airtight cavity. When we breathe, we change the volume of our thorax, which alters the pressure inside it. This causes air to move in or out of the lungs.

There are two movements that bring about ventilation: those of the ribs and the diaphragm. If you put your hands on your chest and breathe in deeply, you can feel your ribs move upwards and outwards. They are moved by the intercostal muscles (Figure 3.5). The outer (external) intercostals contract, pulling the ribs up. At the same time, the muscles of the diaphragm contract, pulling the diaphragm down into a more flattened shape (Figure 3.6a). Both these movements increase the volume of the chest and cause a slight drop in pressure inside the thorax compared with the air outside. Air then enters the lungs (inhalation).

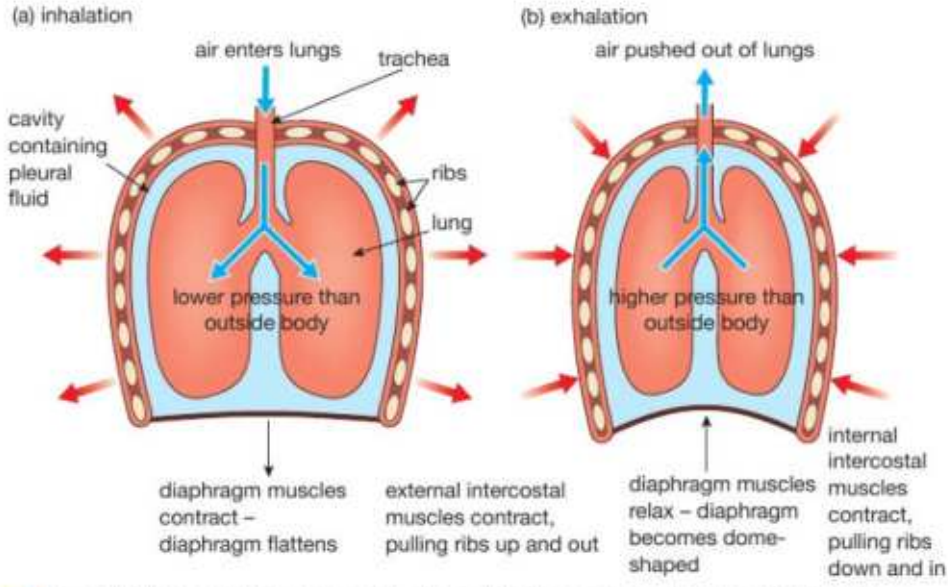
EXTENSION WORK

During normal (shallow) breathing, the elasticity of the lungs and the weight of the ribs acting downwards is enough to cause exhalation. The internal intercostals are only really used for deep (forced) breathing out, for instance when we are exercising.

The opposite happens when you breathe out deeply. The external intercostals relax, and the internal intercostals contract, pulling the ribs down and in. At the same time, the diaphragm muscles relax and the diaphragm goes back to its normal dome shape. The volume of the thorax decreases, and the pressure in the thorax is raised slightly above atmospheric pressure. This time the difference in pressure forces air out of the lungs (Figure 3.6b). Exhalation is helped by the fact that the lungs are elastic, so that they have a tendency to collapse and empty like a balloon.



▲ Figure 3.5 Side view of the chest wall, showing the ribs. The diagram shows how the two sets of intercostal muscles run between the ribs. When the external intercostals contract, they move the ribs upwards. When the internal intercostals contract, the ribs are moved downwards.



▲ Figure 3.6 Changes in the position of the ribs and diaphragm during breathing. (a) Breathing in (inhalation). (b) Breathing out (exhalation).

KEY POINT

It is important that you remember the changes in volume and pressure during ventilation. If you have trouble understanding these, think of what happens when you use a bicycle pump. If you push the pump handle, the air in the pump is squashed, its pressure rises and it is forced out of the pump. If you pull on the handle, the air pressure inside the pump falls a little, and air is drawn in from outside. This is similar to what happens in the lungs. In exams, students sometimes talk about the lungs *forcing* the air in and out – they don't!

GAS EXCHANGE IN THE ALVEOLI

You can tell what is happening during gas exchange if you compare the amounts of different gases in atmospheric air with the air breathed out (Table 3.1).

HINT

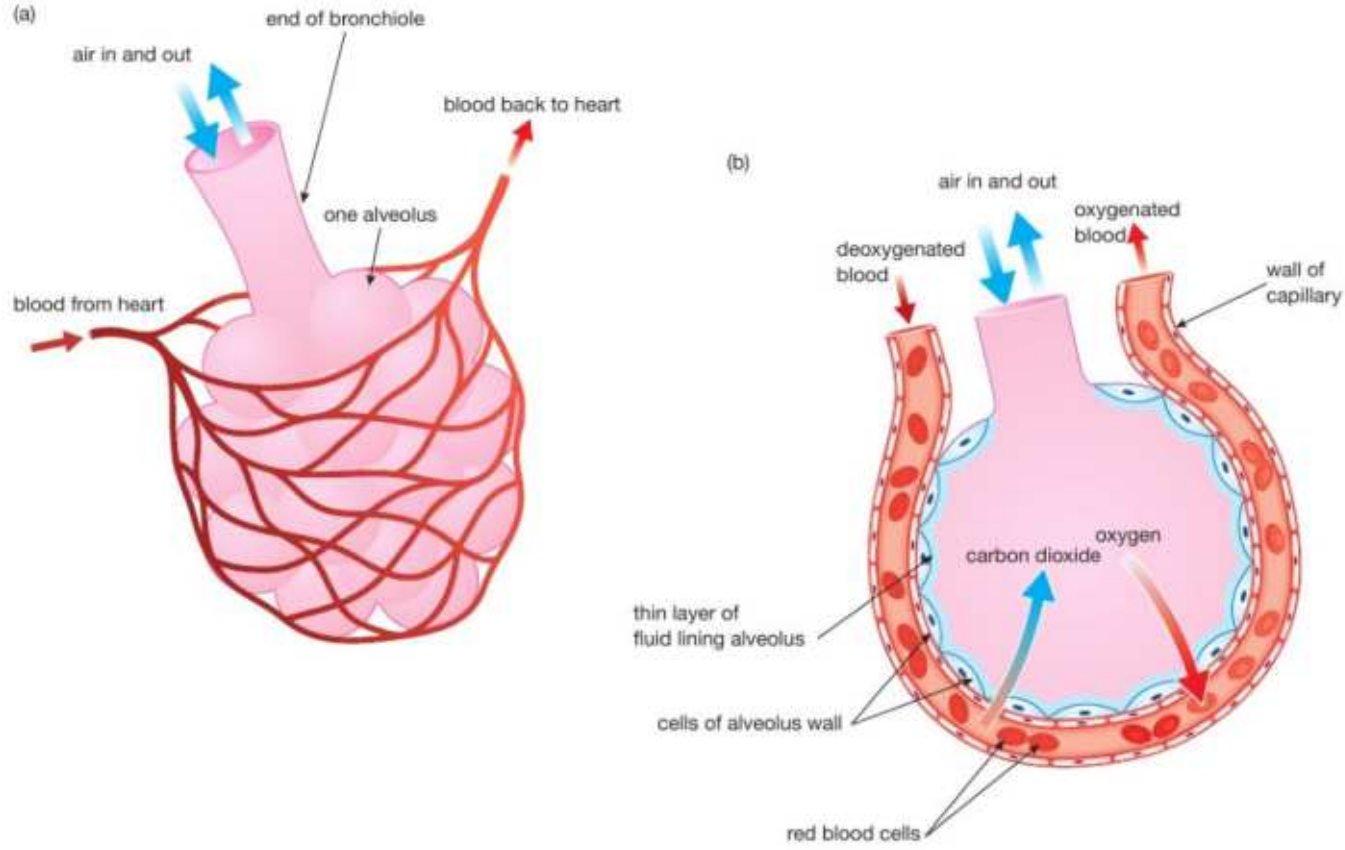
Be careful when interpreting percentages! The *percentage* of a gas in a mixture can vary, even if the actual *amount* of the gas stays the same. This is easiest to understand from an example. Imagine you have a bottle containing a mixture of 20% oxygen and 80% nitrogen. If you used a chemical to absorb all the oxygen in the bottle, the nitrogen left would now be 100% of the gas in the bottle, despite the fact that the *amount* of nitrogen would still be the same. That is why the percentage of nitrogen in inhaled and exhaled air is slightly different.

Table 3.1 Approximate percentage volume of gases in atmospheric (inhaled) and exhaled air.

Gas	Atmospheric air / %	Exhaled air / %
nitrogen	78	79
oxygen	21	16
carbon dioxide	0.04	4
other gases (mainly argon)	1	1

Exhaled air is also warmer than atmospheric air, and is saturated with water vapour. The amount of water vapour in the atmosphere varies depending on weather conditions.

Clearly, the lungs are absorbing oxygen into the blood and removing carbon dioxide from it. This happens in the alveoli. To do this efficiently, the alveoli must have a structure which brings the air and blood very close together, over a very large surface area. There are enormous numbers of alveoli. It has been calculated that the two lungs contain about 700 000 000 of these tiny air sacs, giving a total surface area of 60 m^2. That's bigger than the floor area of an average classroom! Viewed through a high-powered microscope, the alveoli look rather like bunches of grapes, and are covered with tiny blood capillaries (Figure 3.7).



▲ Figure 3.7 (a) Alveoli and the surrounding capillary network. (b) Diffusion of oxygen and carbon dioxide takes place between the air in the alveolus and the blood in the capillaries.

HINT

Be careful – students sometimes write 'The alveolus has *cell walls*'. This statement is not correct – a cell wall is part of a plant cell! The correct way to describe the structure is: 'The alveolus has *a wall made of cells*'.

Deoxygenated blood is pumped from the heart to the lungs and passes through the capillaries surrounding the alveoli. The blood has come from the respiring tissues of the body, where it has given up some of its oxygen to the cells, and gained carbon dioxide. Around the lungs, the blood is separated from the air inside each alveolus by only two cell layers; the cells making up the wall of the alveolus, and the capillary wall itself. This is a distance of less than a thousandth of a millimetre.

EXTENSION WORK

The thin layer of fluid lining the inside of the alveoli comes from the blood. The capillaries and cells of the alveolar wall are 'leaky' and the blood pressure pushes fluid out from the blood plasma into the alveolus. Oxygen dissolves in this moist surface before it passes through the alveolar wall into the blood.

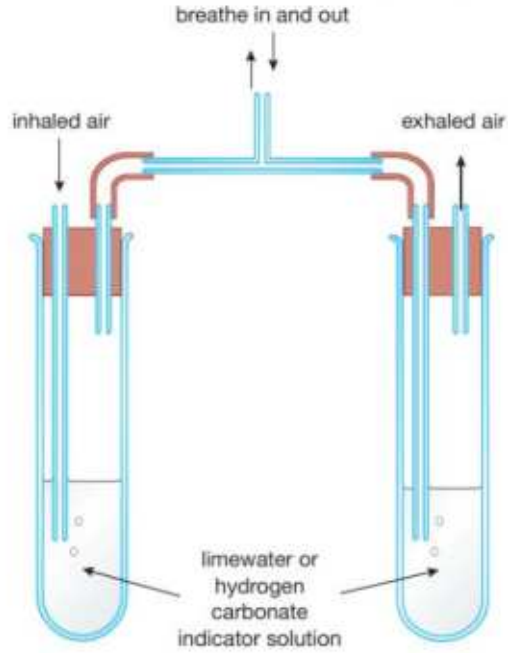
Because the air in the alveolus has a higher concentration of oxygen than the blood entering the **capillary** network, oxygen diffuses from the air, across the wall of the alveolus and into the blood. At the same time there is more carbon dioxide in the blood than there is in the air in the lungs. This means that there is a diffusion gradient for carbon dioxide in the other direction, so carbon dioxide diffuses the other way, out of the blood and into the alveolus. The result is that the blood which leaves the capillaries and flows back to the heart has gained oxygen and lost carbon dioxide. The heart then pumps the oxygenated blood around the body again, to supply the respiring cells (see Chapter 5).

ACTIVITY 1

▼ PRACTICAL: COMPARING THE CARBON DIOXIDE CONTENT OF INHALED AND EXHALED AIR

Safety note: Wear eye protection and breathe gently; do not blow. A clean mouthpiece must be used for each person.

The apparatus in Figure 3.8 can be used to compare the amount of carbon dioxide in inhaled and exhaled air. A person breathes gently in and out through the middle tube. Exhaled air passes out through one tube of indicator solution and inhaled air is drawn in through the other tube. If limewater is used, the limewater in the 'exhaled' tube will turn cloudy before the limewater in the 'inhaled' tube. (If hydrogen carbonate indicator solution is used instead, it changes from red to yellow.)



▲ Figure 3.8 Apparatus for Experiment 6.

ACTIVITY 2

▼ PRACTICAL: AN INVESTIGATION INTO THE EFFECT OF EXERCISE ON BREATHING RATE

Safety note: Wear suitable footwear for exercising and if doing step-ups use a sturdy secure low box or a PE bench.

It is easy to show the effect of exercise on a person's breathing rate. They sit quietly for five minutes, making sure that they are completely relaxed. They then count the number of breaths they take in one minute, recording their results in a table. They wait a minute, and then count their breaths again, recording the result, and repeating if necessary until they get a steady value for the 'resting rate'.

The person then carries out some vigorous exercise, such as running on the spot for three minutes. Immediately after they finish the exercise, they sit down and record the breathing rate as before. They then continue to record their breaths per minute, every minute, until they return to their normal resting rate.

The table shows the results from an investigation into the breathing rate of two girls, A and B, before and after exercise.

Time from start of experiment (min)	Breathing rate / breaths per min	
	A	B
1	13	13
2	14	12
3	14	12
Rate after 3 min vigorous exercise:		
7	28	17
8	24	13
9	17	12
10	14	12

Plot a line graph of these results, using the same axes for both subjects. Join the data points using straight lines, and leave a gap during the period of exercise, when no readings were taken.

Why does breathing rate need to rise during exercise? Explain as fully as possible. Why does the rate not return to normal as soon as a subject finishes the exercise? (see Chapter 1).

Describe the difference in the breathing rates of the two girls (A and B) after exercise. Which girl is more fit? Explain your reasoning.

THE EFFECTS OF SMOKING

In order for the lungs to exchange gases properly, the air passages need to be clear, the alveoli need to be free from dirt particles and bacteria, and they must have as big a surface area as possible in contact with the blood. There is one habit that can upset all of these conditions – smoking.

Links between smoking and diseases of the lungs are now a proven fact. Smoking is associated with lung cancer, bronchitis and emphysema. It is also a major contributing factor to other conditions, such as coronary heart disease and ulcers of the stomach and intestine. Pregnant women who smoke are more likely to give birth to underweight babies.

Coronary heart disease will be described in Chapter 5 after you have studied the structure of the heart. Here we will look at a number of other medical conditions that are caused by smoking.

EFFECTS OF SMOKE ON THE LINING OF THE AIR PASSAGES

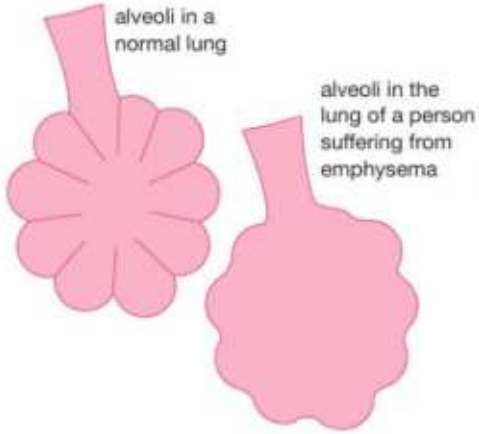
You saw above how the lungs are kept free of particles of dirt and bacteria by the action of mucus and cilia. In the trachea and bronchi of a smoker, the cilia are destroyed by the chemicals in cigarette smoke.

The reduced numbers of cilia mean that the mucus is not swept away from the lungs, but remains to block the air passages. This is made worse by the fact that the smoke irritates the lining of the airways, stimulating the cells to secrete more mucus. The sticky mucus blocking the airways is the source of 'smoker's cough'. Irritation of the bronchial tree, along with infections from bacteria in the mucus, can cause the lung disease **bronchitis**. Bronchitis blocks normal air flow, so the sufferer has difficulty breathing properly.

EMPHYSEMA

Emphysema is another lung disease that kills about 20 000 people in Britain every year. Smoking is the cause of one type of emphysema. Smoke damages the walls of the alveoli, which break down and fuse together again, forming enlarged, irregular air spaces (Figure 3.9).

This greatly reduces the surface area for gas exchange, which becomes very inefficient. The blood of a person with emphysema carries less oxygen. In serious cases, this leads to the sufferer being unable to carry out even mild exercise, such as walking. Emphysema patients often have to have a supply of oxygen nearby at all times (Figure 3.10). There is no cure for emphysema, and usually the sufferer dies after a long and distressing illness.



▲ Figure 3.9 The alveoli of a person suffering from emphysema have a greatly reduced surface area and inefficient gas exchange.



▲ Figure 3.10 Patients with emphysema often need to breathe air enriched with oxygen in order to stay alive.

EXTENSION WORK

A person who has chronic (long-term) bronchitis and emphysema is said to be suffering from chronic obstructive pulmonary disease, or COPD. COPD is a progressive disease for which there is no cure.

LUNG CANCER

Evidence of the link between smoking and lung cancer first appeared in the 1950s. In one study, a number of patients in hospital were given a series of questions about their lifestyles. They were asked about their work, hobbies, housing and so on, including a question about how many cigarettes they smoked. The same questionnaire was given to two groups of patients. The first group were all suffering from lung cancer. The second (**Control**) group were in hospital with various other illnesses, but not lung cancer. To make it a fair comparison, the Control patients were matched with the lung cancer patients for sex, age and so on.

When the results were compared, one difference stood out (Table 3.2). A greater proportion of the lung cancer patients were smokers than in the Control patients. There seemed to be a connection between smoking and getting lung cancer.

Table 3.2 Comparison of the smoking habits of lung cancer patients and other patients.

	Percentage of patients who were non-smokers	Percentage of patients who smoked more than 15 cigarettes a day
lung cancer patients	0.5	25
Control patients (with illnesses other than lung cancer)	4.5	13



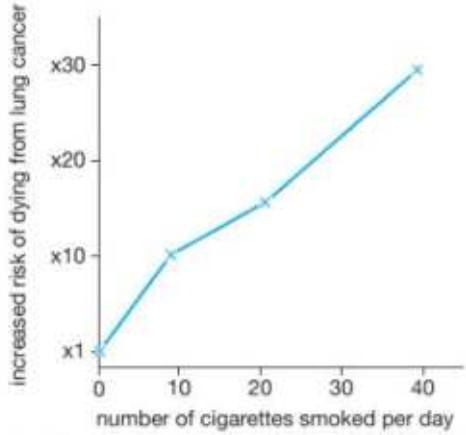
▲ Figure 3.11 This lung is from a patient with lung cancer.

Although the results didn't prove that smoking caused lung cancer, there was a statistically significant link between smoking and the disease: this is called a 'correlation'.

Over 20 similar investigations in nine countries have revealed the same findings. In 1962 a report called 'Smoking and health' was published by the Royal College of Physicians of London, which warned the public about the dangers of smoking. Not surprisingly, the first people to take the findings seriously were doctors, many of whom stopped smoking. This was reflected in their death rates from lung cancer. In ten years, while deaths among the general male population had risen by 7%, the deaths of male doctors from the disease had *fallen* by 38%.

Cigarette smoke contains a strongly addictive drug – **nicotine**. Smoke contains over 7000 chemicals, including; carbon monoxide, arsenic, ammonia, formaldehyde, cyanide, benzene, and toluene. More than 60 of the chemicals are known to cause cancer. These chemicals are called **carcinogens**, and are contained in the tar that collects in a smoker's lungs. Cancer happens when cells mutate and start to divide uncontrollably, forming a **tumour** (Figure 3.11). If a lung cancer patient is lucky, they may have the tumour removed by an operation before the cancer cells spread to other tissues of the body. Unfortunately tumours in the lungs usually cause no pain, so they are not discovered until it is too late – it may be inoperable, or tumours may have developed elsewhere.

If you smoke you are not *bound* to get lung cancer, but the risk that you will get it is much greater. In fact, the more cigarettes you smoke, the more the risk increases (Figure 3.12).



▲ Figure 3.12 The more cigarettes a person smokes, the more likely it is they will die of lung cancer. For example, smoking 20 cigarettes a day increases the risk by about 15 times.

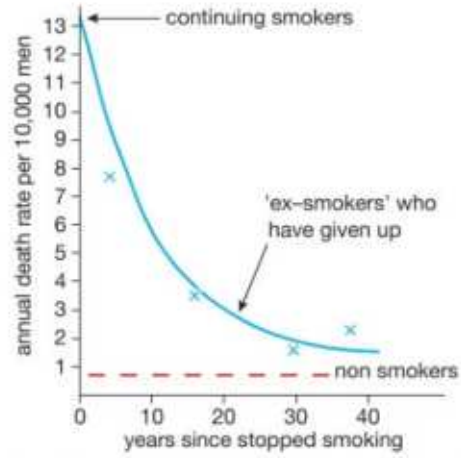
The obvious thing to do is not to start smoking. However, if you are a smoker, giving up the habit soon improves your chance of survival (Figure 3.13). After a few years, the likelihood of your dying from a smoking-related disease is almost back to the level of a non-smoker.

DID YOU KNOW?

People often talk about 'yellow nicotine stains'. In fact it is the *tar* that stains a smoker's fingers and teeth. Nicotine is a colourless, odourless chemical.

DID YOU KNOW?

Studies have shown that the type of cigarette smoked makes very little difference to the smoker's risk of getting lung cancer. Filtered and 'low tar' cigarettes only reduce the risk slightly.



▲ Figure 3.13 Death rates from lung cancer for smokers, non-smokers and ex-smokers.

CARBON MONOXIDE IN SMOKE

One of the harmful chemicals in cigarette smoke is the poisonous gas **carbon monoxide**. When this gas is breathed in with the smoke, it enters the bloodstream and interferes with the ability of the blood to carry oxygen. Oxygen is carried around in the blood in the red blood cells, attached to a chemical called **haemoglobin** (see Chapter 5). Carbon monoxide can combine with the haemoglobin much more tightly than oxygen can, forming a compound called **carboxyhaemoglobin**. The haemoglobin will combine with carbon monoxide in preference to oxygen. When this happens, the blood carries much less oxygen around the body. Carbon monoxide from smoking is also a major cause of heart disease (Chapter 5).

If a pregnant woman smokes, she will be depriving her unborn **fetus** of oxygen (Figure 3.14). This has an effect on its growth and development, and leads to the mass of the baby at birth being lower, on average, than the mass of babies born to non-smokers.

SOME SMOKING STATISTICS

- It is estimated that there are over 1 billion smokers worldwide. In 2014 they consumed 5.8 *trillion* cigarettes.
- Every year nearly 6 million people are killed by tobacco-related illnesses. If the current trend continues, by 2030 this will rise to 8 million deaths per year and 80% of these premature deaths will be in developing countries.
- Smoking causes almost 80% of deaths from lung cancer, 80% of deaths from bronchitis and emphysema, and 14% of deaths from heart disease.
- More than a quarter of all cancer deaths are attributable to smoking. These include cancer of the lung, mouth, lip, throat, **bladder**, kidney, pancreas, stomach, liver and cervix.
- While demand for tobacco has steadily fallen in developed countries like the UK, cigarette consumption is being increasingly concentrated in the developing world.
- 9.6 million adults in the UK smoke cigarettes, 20% of men and 17% of women. However, 22% of women and 30% of men in the UK are now ex-smokers. Surveys show that about two-thirds of current smokers would like to stop smoking.
- It is estimated that worldwide, 31% of men and 8% of women are smokers. Consumption varies widely between different countries, but generally the areas of the world where there has been no change in consumption, or an increase, are southern and central Asia, Eastern Europe and Africa.

- In China alone there are about 350 million smokers, who consume about one-third of all cigarettes smoked worldwide. Large multinational tobacco companies have long been keen to enter the Chinese market.
- In China there are over a million deaths a year from smoking-related diseases. This figure is expected to double by 2025.
- In developing countries, smoking has a greater economic impact. Poorer smokers spend significant amounts of their income on cigarettes rather than necessities like food, healthcare and education.
- Tobacco farming uses up land that could be used for growing food crops. In 2012, 7.5 million tonnes of tobacco leaf were grown on almost 4.3 million hectares of land (an area larger than Switzerland).

Sources: Action on Smoking and Health (ASH) fact sheets (2015- 2016); ASH research reports (2014-2016)]

GIVING UP SMOKING

Most smokers admit that they would like to find a way to give up the habit. The trouble is that the nicotine in tobacco is a very addictive drug, and causes withdrawal symptoms when people stop smoking. These include cravings for a cigarette, restlessness and a tendency to put on weight (nicotine depresses the appetite).

There are various ways that smokers can be helped to give up their habit. One method is 'vaping', which involves inhaling a vapour containing nicotine from an electronic cigarette or e-cigarette (Figure 3.15). Other methods use nicotine patches (Figure 3.16) or nicotine chewing gum. They all work in a similar way, providing the smoker with a source of nicotine without the harmful tar from cigarettes. The nicotine is absorbed by the body and reduces the craving for a cigarette. Gradually, the patient reduces the nicotine dose until they are weaned off the habit.

EXTENSION WORK

You could carry out an Internet search to find out about the different methods people use to help them give up smoking. Which methods have the highest success rate? Is there any evidence that suggests e-cigarettes are not safe?

There are several other ways that people use to help them give up smoking, including the use of drugs that reduce withdrawal symptoms, acupuncture and even hypnotism.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

More questions on breathing can be found at the end of Unit 2 on page 116.

1 The structures below are found in the human bronchial tree

1. alveoli
2. trachea
3. bronchioles
4. bronchi

Which of the following shows the route taken by air after it is breathed in through the mouth?

A 2 → 3 → 4 → 1
B 1 → 4 → 3 → 2
C 2 → 4 → 3 → 1
D 4 → 1 → 2 → 3

2 Which of the following is *not* a feature of an efficient gas exchange surface?

A thick walls
B moist lining
C close proximity to blood capillaries
D large surface area

SKILLS CRITICAL THINKING

3 Which row in the table shows the correct percentage of oxygen in atmospheric and exhaled air?

	Atmospheric air / %	Exhaled air / %
A	78	21
B	21	16
C	16	4
D	4	0.04

4 Chemicals in cigarette smoke lead to the breakdown of the walls of the alveoli. What is the name given to this disease?

A bronchitis
B emphysema
C coronary heart disease
D lung cancer

5 Copy and complete the table, which shows what happens in the thorax during ventilation of the lungs. Two boxes have been completed for you.

	Action during inhalation	Action during exhalation
external intercostal muscles	contract	
internal intercostal muscles		
ribs		move down and in
diaphragm		
volume of thorax		
pressure in thorax		
volume of air in lungs		

6 A student wrote the following about the lungs.

When we breathe in, our lungs inflate, sucking air in and pushing the ribs up and out, and forcing the diaphragm down. This is called respiration. In the air sacs of the lungs, the air enters the blood. The blood then takes the air around the body, where it is used by the cells. The blood returns to the lungs to be cleaned. When we breathe out, our lungs deflate, pulling the diaphragm up and the ribs down. The stale air is pushed out of the lungs.

The student did not have a good understanding of the workings of the lungs. Re-write their description, using correct biological words and ideas.

SKILLS REASONING

7 Sometimes, people injured in an accident such as a car crash suffer from a *pneumothorax*. This is an injury where the chest wall is punctured, allowing air to enter the pleural cavity (see Figure 3.1). A patient was brought to the casualty department of a hospital, suffering from a pneumothorax on the left side of his chest. His left lung had collapsed, but he was able to breathe normally with his right lung.

a Explain why a pneumothorax caused the left lung to collapse.
b Explain why the right lung was not affected.
c If a patient's lung is injured or infected, a surgeon can sometimes 'rest' it by performing an operation called an *artificial pneumothorax*. What do you think might be involved in this operation?

SKILLS CRITICAL THINKING

8 Briefly explain the importance of the following.

a The trachea wall contains C-shaped rings of cartilage.

b The distance between the air in an alveolus and the blood in an alveolar capillary is less than 1/1000th of a millimetre.

c The lining of the trachea contains mucus-secreting cells and cells with cilia.

d Smokers have a lower concentration of oxygen in their blood than non-smokers.

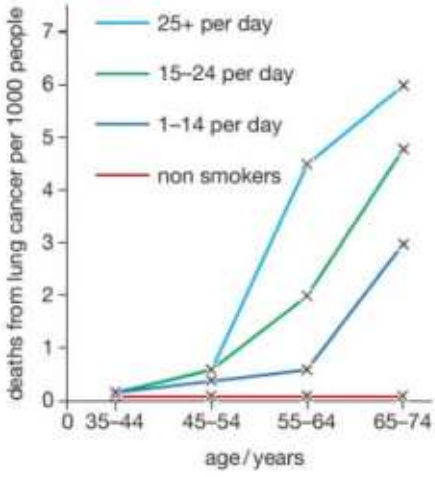
e Nicotine patches and nicotine chewing gum can help someone give up smoking.

f The lungs have a surface area of about 60 m^2 and a good blood supply.

9 Explain the differences between the lung diseases bronchitis and emphysema.

SKILLS ANALYSIS

10 A long-term investigation was carried out into the link between smoking and lung cancer. The smoking habits of male doctors aged 35 or over were determined while they were still alive, then the number and causes of deaths among them were monitored over a number of years. (Note that this survey was carried out in the 1950s – very few doctors smoke these days!) The results are shown in the graph.



a Write a paragraph to explain what the researchers found out from the investigation.

SKILLS ANALYSIS, PROBLEM SOLVING

b How many deaths from lung cancer would be expected for men aged 55 who smoked 25 cigarettes a day up until their death? How many deaths from lung cancer would be expected for men in the same age group smoking 10 a day?

SKILLS ANALYSIS, REASONING

c Table 3.2 (page 43) shows the findings of another study linking lung cancer with smoking. Which do you think is the more convincing evidence of the link, this investigation or the findings illustrated in Table 3.2?

SKILLS CREATIVITY

11 Design and make a hard-hitting leaflet explaining the link between smoking and lung cancer. It should be aimed at encouraging an adult smoker to give up the habit. You could use suitable computer software to produce your design. Include some smoking statistics, perhaps from an Internet search. However don't use too many, or they may put the person off reading the leaflet!

4 FOOD AND DIGESTION

Food is essential for life. The nutrients obtained from it are used in many different ways by the body. This chapter looks at the different kinds of food, and how the food is broken down by the digestive system and absorbed into the blood, so that it can be carried to all the tissues of the body.

LEARNING OBJECTIVES

- Identify the chemical elements present in carbohydrates, proteins and lipids (fats and oils)
- Describe the structure of carbohydrates, proteins and lipids as large molecules made up from smaller basic units – starch and glycogen from simple sugars, protein from amino acids, and lipids from fatty acids and glycerol
- Investigate food samples for the presence of glucose, starch, protein and fat
- Understand that a balanced diet should include appropriate proportions of carbohydrate, protein, lipid, vitamins, minerals, water and dietary fibre
- Identify the sources and describe the functions of carbohydrate, lipid, protein, vitamins A, C and D, the mineral ions calcium and iron, water, and dietary fibre as components of the diet
- Understand how energy requirements vary with activity levels, age and pregnancy
- Describe the structure and function of the human alimentary canal, including the mouth, oesophagus, stomach, small intestine (duodenum and ileum), large intestine (colon and rectum) and pancreas
- Understand how food is moved through the gut by peristalsis
- Understand the role of digestive enzymes, including the digestion of starch to glucose by amylase and maltase, the digestion of proteins to amino acids by proteases and the digestion of lipids to fatty acids and glycerol by lipases
- Understand that bile is produced by the liver and stored in the gall bladder, and understand the role of bile in neutralising stomach acid and emulsifying lipids
- Understand how the small intestine is adapted for absorption, including the structure of a villus



▲ Figure 4.1 A balanced diet contains all the types of food the body needs, in just the right amounts.

We need food for three main reasons:

- to supply us with a 'fuel' for energy
- to provide materials for growth and repair of tissues
- to help fight disease and keep our bodies healthy.

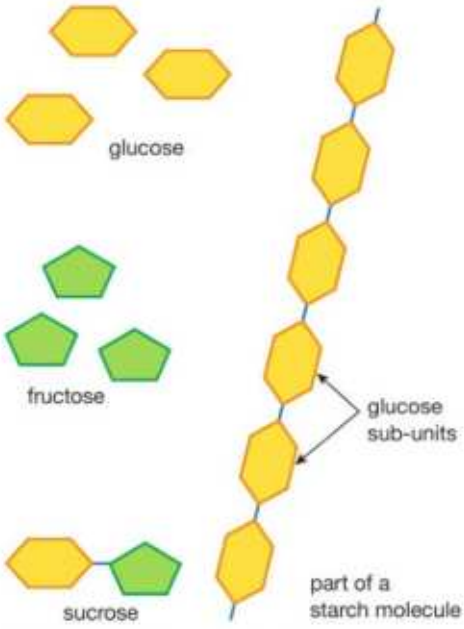
A BALANCED DIET

The food that we eat is called our diet. No matter what you like to eat, your diet must include the following five groups of food substances if your body is to work properly and stay healthy – **carbohydrates**, **lipids**, **proteins**, **minerals** and **vitamins** – along with **dietary fibre** and water. Food should provide you with all of these substances, but they must also be present in the *right* amounts. A diet that provides enough of these substances and in the correct proportions to keep you healthy is called a **balanced diet** (Figure 4.1). We will look at each type of food in turn, to find out about its chemistry and the role that it plays in the body.

CARBOHYDRATES

DID YOU KNOW?

The chemical formula for glucose is $C_6H_{12}O_6$. Like all carbohydrates, glucose contains only the elements carbon, hydrogen and oxygen. The 'carbo' part of the name refers to carbon, and the 'hydrate' part refers to the fact that the hydrogen and oxygen atoms are in the ratio two to one, as in water (H_2O).



▲ Figure 4.2 Glucose and fructose are 'single sugar' molecules. A molecule of glucose joined to a molecule of fructose forms the 'double sugar' called sucrose. Starch is a polymer of many glucose sub-units.

Carbohydrates only make up about 1% of the mass of the human body, but they have a very important role. They are the body's main 'fuel' for supplying cells with energy. Cells release this energy by oxidising a sugar called **glucose**, in the process called cell respiration (see Chapter 1). Glucose and other sugars belong to one group of carbohydrates.

Glucose is found naturally in many sweet-tasting foods, such as fruits and vegetables. Other foods contain different sugars, such as the fruit sugar called **fructose**, and the milk sugar, **lactose**. Ordinary table sugar, the sort some people put in their tea or coffee, is called **sucrose**. Sucrose is the main sugar that is transported through plant stems. This is why we can extract it from sugar cane, which is the stem of a large grass-like plant. Sugars have two physical properties that you will probably know: they all taste sweet, and they are all soluble in water.

We can get all the sugar we need from natural foods such as fruits and vegetables, and from the **digestion** of starch. Many processed foods contain large amounts of *added* sugar. For example, a typical can of cola can contain up to seven teaspoons (27 g) of sugar! There is hidden sugar in many other foods. A tin of baked beans contains about 10 g of added sugar. This is on top of all the food that we eat with a more obvious sugar content, such as cakes, biscuits and sweets.

In fact, we get most of the carbohydrate in our diet not from sugars, but from **starch**. Starch is a large, *insoluble* molecule. Because it does not dissolve, it is found as a storage carbohydrate in many plants, such as potato, rice, wheat and millet. The 'staple diets' of people from around the world are starchy foods like rice, potatoes, bread and pasta. Starch is a polymer of glucose – it is made of long chains of hundreds of glucose molecules joined together (Figure 4.2).

Starch is only found in plant tissues, but animal cells sometimes contain a very similar carbohydrate called **glycogen**. This is also a polymer of glucose, and is found in tissues such as liver and muscle, where it acts as a store of energy for these organs.

As you will see, large carbohydrates such as starch and glycogen have to be broken down into simple sugars during digestion, so that they can be absorbed into the blood.

Another carbohydrate that is a polymer of glucose is **cellulose**, the material that makes up plant cell walls. Humans are *not* able to digest cellulose, because our gut doesn't make the enzyme needed to break down the cellulose molecule. This means that we are not able to use cellulose as a source of energy. However, it still has a vitally important function in our diet. It forms **dietary fibre** or 'roughage', which gives the muscles of the gut something to push against as the food is moved through the intestine. This keeps the gut contents moving, avoiding constipation and helping to prevent serious diseases of the intestine, such as colitis and bowel cancer.

EXTENSION WORK

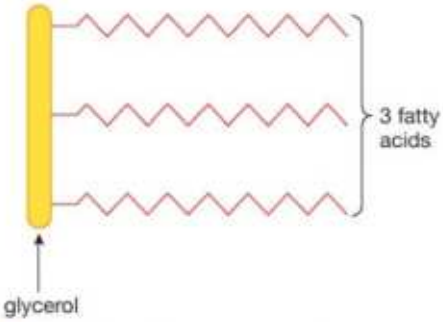
'Single' sugars such as glucose and fructose are called **monosaccharides**. Sucrose molecules are made of two monosaccharides (glucose and fructose) joined together, so sucrose is called a **disaccharide**. Lactose is also a disaccharide, made of glucose joined to another monosaccharide called galactose. Polymers of sugars, such as starch, glycogen and cellulose, are called polysaccharides.

LIPIDS (FATS AND OILS)

Lipids contain the same three elements as carbohydrates – carbon, hydrogen and oxygen – but the proportion of oxygen in a lipid is much lower than in a carbohydrate. For example, beef and lamb both contain a fat called tristearin, which has the formula $C_{51}H_{98}O_6$. This fat, like other animal fats, is a solid at room



▲ Figure 4.3 These foods are all rich in lipids.



▲ Figure 4.4 Lipids are made up of a molecule of glycerol joined to three fatty acids. The many different fatty acids form the variable part of the molecule.

KEY POINT

Cholesterol is a substance that the body gets from food such as eggs and meat, but we also make cholesterol in our liver. It is an essential part of all cells, but too much cholesterol causes heart disease.

temperature, but melts if you warm it up. On the other hand, plant lipids are usually liquid at room temperature, and are called oils. Meat, butter, cheese, milk, eggs and oily fish are all rich in animal fats, as well as foods fried in animal fat. Vegetable oils include many types used for cooking, such as olive oil, corn oil and rapeseed oil, as well as products made from oils, such as margarine (Figure 4.3).

Lipids make up about 10% of our body's mass. They form an essential part of the structure of all cells, and fat is deposited in certain parts of the body as a long-term store of energy, for example under the skin and around the heart and kidneys. The fat layer under the skin acts as insulation, reducing heat loss through the surface of the body. Fat around organs such as the kidneys also helps to protect them from mechanical damage.

The chemical 'building blocks' of lipids are two types of molecule called **glycerol** and **fatty acids**. Glycerol is an oily liquid. It is also known as glycerine, and is used in many types of cosmetics. In lipids, a molecule of glycerol is joined to three fatty acid molecules. There are many different fatty acid molecules, which give us the many different kinds of lipid found in food (Figure 4.4).

Although lipids are an essential part of our diet, too much lipid is unhealthy, especially a type called *saturated* fat, and a lipid compound called **cholesterol**. These substances have been linked to heart disease (see Chapter 5).

DID YOU KNOW?

Saturated lipids (saturated fats) are more common in food from animal sources, such as meat and dairy products. 'Saturated' is a word used in chemistry, which means that the fatty acids of the lipids contain no double bonds. Other lipids are *unsaturated*, which means that their fatty acids contain double bonds. These are more common in plant oils. There is evidence that unsaturated lipids are healthier for us than saturated ones.

PROTEINS



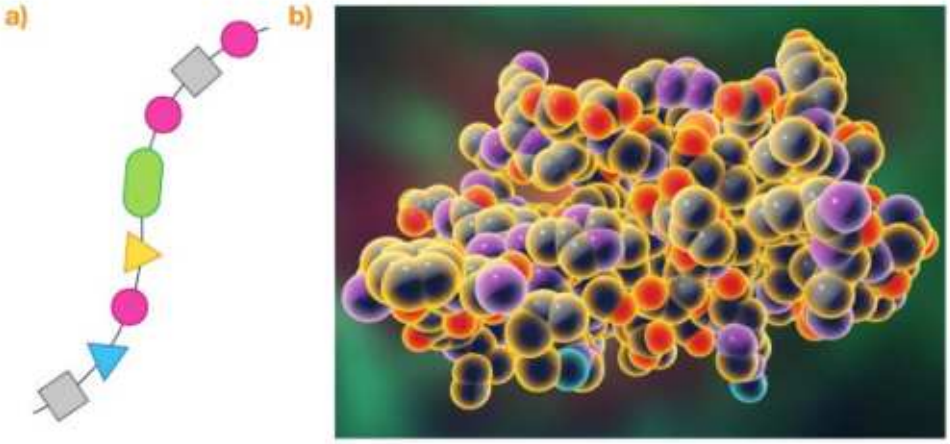
▲ Figure 4.5 This child is suffering from a lack of protein in his diet, a disease called kwashiorkor. His swollen belly is not due to a full stomach, but is caused by fluid collecting in the tissues. Other symptoms include loss of weight, poor muscle growth, general weakness and flaky skin.

Proteins make up about 18% of the mass of the body. This is the second largest percentage after water. All cells contain protein, so we need it for growth and repair of tissues. Many compounds in the body are made from protein, including enzymes.

Most foods contain some protein, but certain foods such as meat, fish, cheese and eggs are particularly rich in it. You will notice that these foods are animal products. Plant material generally contains less protein, but some foods, especially beans, peas and nuts, are richer in protein than others.

However, we don't need much protein in our diet to stay healthy. Doctors recommend a maximum daily intake of about 70 g. In more economically developed countries, people often eat far more protein than they need, whereas in many poorer countries a protein-deficiency disease called **kwashiorkor** is common (Figure 4.5).

Like starch, proteins are also polymers, but whereas starch is made from a single molecular building block (glucose), proteins are made from 20 different sub-units called **amino acids**. All amino acids contain four chemical elements: carbon, hydrogen and oxygen (as in carbohydrates and fats) along with nitrogen. Two amino acids also contain sulfur. The amino acids are linked together in long chains, which are usually folded up or twisted into spirals, with cross-links holding the chains together (Figure 4.6).



▲ Figure 4.6 (a) A chain of amino acids forming part of a protein molecule. Each shape represents a different amino acid. (b) A computer model of the protein insulin. This substance, like all proteins, is made of a long chain of amino acids arranged in a particular order and folded into a specific shape.

EXTENSION WORK

Humans can make about half of the 20 amino acids that they need, but the other 10 have to be taken in as part of the diet. These 10 are called essential amino acids. There are higher amounts of essential amino acids in meat, fish, eggs and dairy products. If you are a vegetarian, you can still get all the essential amino acids you need, as long as you eat a varied diet that includes a range of different plant materials.

The *shape* of a protein is very important in allowing it to carry out its function, and the *order* of amino acids in the protein decides its shape. Because there are 20 different amino acids, and they can be arranged in any order, the number of different protein structures that can be made is enormous. As a result, there are thousands of different kinds of proteins in organisms, from structural proteins such as collagen and keratin in skin and nails, to proteins with more specific functions, such as enzymes and haemoglobin.

MINERALS

All the foods you have read about so far are made from just five chemical elements: carbon, hydrogen, oxygen, nitrogen and sulfur. Our bodies contain many other elements that we get from our food as 'minerals' or 'mineral ions'. Some are present in large amounts in the body, for example calcium, which is used for making teeth and bones. Others are present in much smaller amounts, but still have essential jobs to do. For instance our bodies contain about 3 g of iron, but without it our blood would not be able to carry oxygen. Table 4.1 shows just a few of these minerals and the reasons they are needed.

Table 4.1 Some examples of minerals needed by the body.

Mineral	Approximate mass in an adult body / g	Location or role in body	Examples of foods rich in minerals
calcium	1000	making teeth and bones	dairy products, fish, bread, vegetables
phosphorus	650	making teeth and bones; part of many chemicals, e.g. DNA and ATP	most foods
sodium	100	in body fluids, e.g. blood	common salt, most foods
chlorine	100	in body fluids, e.g. blood	common salt, most foods
magnesium	30	making bones; found inside cells	green vegetables
iron	3	part of haemoglobin in red blood cells, helps carry oxygen	red meat, liver, eggs, some vegetables, e.g. spinach



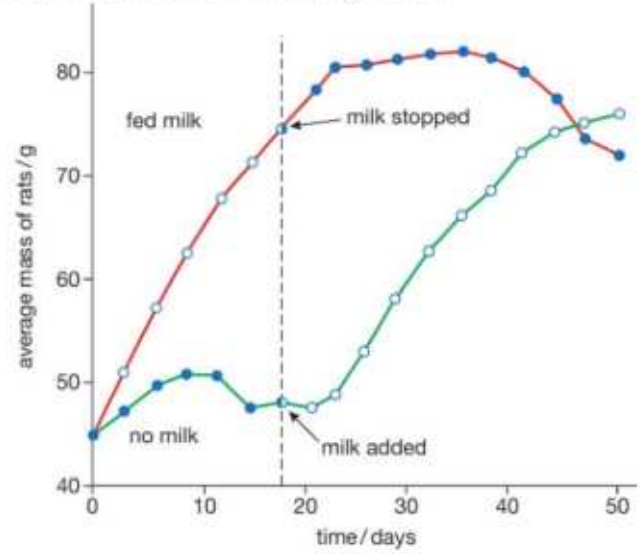
▲ Figure 4.7 An x-ray of the legs of a child showing the symptoms of rickets.

If a person doesn't get enough of a mineral from their diet, they will show the symptoms of a 'mineral deficiency disease'. For example, a one-year-old child needs to consume about 0.6 g (600 mg) of calcium every day, to make the bones grow properly and harden. Anything less than this over a prolonged period could result in poor bone development. The bones become deformed, a disease called rickets (Figure 4.7). Rickets can also be caused by lack of vitamin D in the diet (see below).

Similarly, 16-year-olds need about 12 mg of iron in their daily food intake. If they don't get this amount, they can't make enough haemoglobin for their red blood cells (see Chapter 5). This causes a condition called anaemia. People who are anaemic become tired and lack energy, because their blood doesn't carry enough oxygen.

VITAMINS

During the early part of the twentieth century, experiments were carried out that identified another class of food substances. When young laboratory rats were fed a diet of pure carbohydrate, lipid and protein, they all became ill and died. If they were fed on the same pure foods with a little added milk, they grew normally. The milk contained chemicals that the rats needed in small amounts to stay healthy. These chemicals are called vitamins. The results of one of these experiments are shown in Figure 4.8.



▲ Figure 4.8 Rats were fed a diet of pure carbohydrate, lipid and protein, with and without added milk. Vitamins in the milk had a dramatic effect on their growth.

At first, the chemical nature of vitamins was not known, and they were given letters to distinguish between them, such as vitamin A, vitamin B and so on. Each was identified by the effect a lack of the vitamin (vitamin deficiency) had on the body. For example, vitamin D is needed for growing bones to take up calcium salts. A deficiency of this vitamin can result in rickets (Figure 4.7), just as a lack of calcium can.

We now know the chemical structure of the vitamins and the exact ways in which they work in the body. As with vitamin D, each has a particular function. Vitamin A is needed to make a light-sensitive chemical in the retina of the eye (see Chapter 6). A lack of this vitamin causes night blindness, where the

DID YOU KNOW?

The cure for scurvy was discovered as long ago as 1753. Sailors on long voyages often got scurvy because they ate very little fresh fruit and vegetables (the main source of vitamin C). A ship's doctor called James Lind wrote an account of how the disease could quickly be cured by eating fresh oranges and lemons. The famous explorer Captain Cook, on his world voyages in 1772 and 1775, kept his sailors healthy by making sure that they ate fresh fruit. By 1804, all British sailors were made to drink lime juice to prevent scurvy. This is how they came to be called 'limeys', a word that was later used by Americans for all British people.

person finds it difficult to see in dim light. Vitamin C is needed to make fibres of a material called connective tissue. This acts as a 'glue', bonding cells together in a tissue. It is found in the walls of blood vessels and in the skin and lining surfaces of the body. Vitamin C deficiency leads to a disease called **scurvy**, where wounds fail to heal, and bleeding occurs in various places in the body. This is especially noticeable in the gums (Figure 4.9).



▲ Figure 4.9 Vitamin C helps lining cells such as those in the mouth and gums stick to each other. Lack of vitamin C causes scurvy, where the mouth and gums become damaged and bleed.

Vitamin B is not a single substance, but a collection of many different substances called the vitamin B group. It includes vitamins B1 (thiamine), B2 (riboflavin) and B3 (niacin). These compounds are involved in the process of cell respiration. Different deficiency diseases result if any of them are missing from the diet. For example, lack of vitamin B1 results in the weakening of the muscles and paralysis, a disease called **beri-beri**.

The main vitamins, their role in the body and some foods which are good sources of each, are summarised in Table 4.2.

Notice that the amounts of vitamins that we need are very small, but we cannot stay healthy without them.

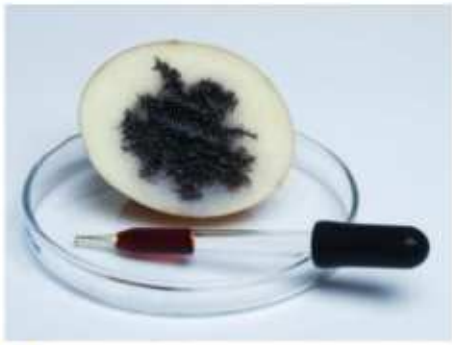
Table 4.2 Summary of the main vitamins. Note that you only need remember the sources and functions of vitamins A, C and D.

Vitamin	Recommended daily amount in diet[1]	Use in the body	Effect of deficiency	Some foods that are a good source of the vitamin
A	0.8 mg	making a chemical in the retina; also protects the surface of the eye	night blindness, damaged cornea of eye	fish liver oils, liver, butter, margarine, carrots
B1	1.1 mg	helps with cell respiration	beri-beri	yeast extract, cereals
B2	1.4 mg	helps with cell respiration	poor growth, dry skin	green vegetables, eggs, fish
B3	16 mg	helps with cell respiration	pellagra (dry red skin, poor growth, and digestive disorders)	liver, meat, fish.
C	80 mg	sticks together cells lining surfaces such as the mouth	scurvy	fresh fruit and vegetables
D	5 μg	helps bones absorb calcium and phosphate	rickets, poor teeth	fish liver oils; also made in skin in sunlight

[1]Figures are the European Union's recommended daily intake for an adult (2012). 'mg' stands for milligram (a thousandth of a gram) and 'μg' for microgram (a millionth of a gram).

FOOD TESTS

It is possible to carry out simple chemical tests to find out if a food contains starch, glucose, protein or lipid. Practical 8 uses pure substances for the tests, but it is possible to do them on normal foods too. Unless the food is a liquid like milk, it needs to be cut up into small pieces and ground with a pestle and mortar, then shaken with some water in a test tube. This is done to extract the components of the food and dissolve any soluble substances such as sugars.



▲ Figure 4.10a Testing for starch using iodine



▲ Figure 4.10b Glucose with Benedict's solution, before and after heating

ACTIVITY 3

▼ PRACTICAL: TEST FOR STARCH

A little starch is placed on a spotting tile. A drop of yellow-brown iodine solution is added to the starch. The iodine reacts with the starch, forming a very dark blue, or 'blue-black' colour (Figure 4.10 (a)). Starch is insoluble, but this test will work on a solid sample of food, such as potato, or a suspension of starch in water.

▼ PRACTICAL: TEST FOR GLUCOSE

Glucose is called a reducing sugar. This is because the test for glucose involves reducing an alkaline solution of copper (II) sulfate to copper (I) oxide.

A small spatula measure of glucose is placed in a test tube and a little water added (about 2 cm deep). The tube is shaken to dissolve the glucose. Several drops of Benedict's solution are added to the tube, enough to colour the mixture blue (Figure 4.10 (b)).

A water bath is prepared by half-filling a beaker with water and heating it on a tripod and gauze. The test tube is placed in the beaker and the water allowed to boil (using a water bath is safer than heating the tube directly in the Bunsen burner). After a few seconds the clear blue solution gradually changes colour, forming a cloudy orange or 'brick red' precipitate of copper (I) oxide (Figure 4.10 (b)).

All other 'single' sugars (monosaccharides), such as fructose, are reducing sugars, as well as some 'double' sugars (disaccharides), such as the milk sugar, lactose. However, ordinary table sugar (sucrose) is not. If sucrose is boiled with Benedict's solution it will stay a clear blue colour.

▼ PRACTICAL: TEST FOR PROTEIN

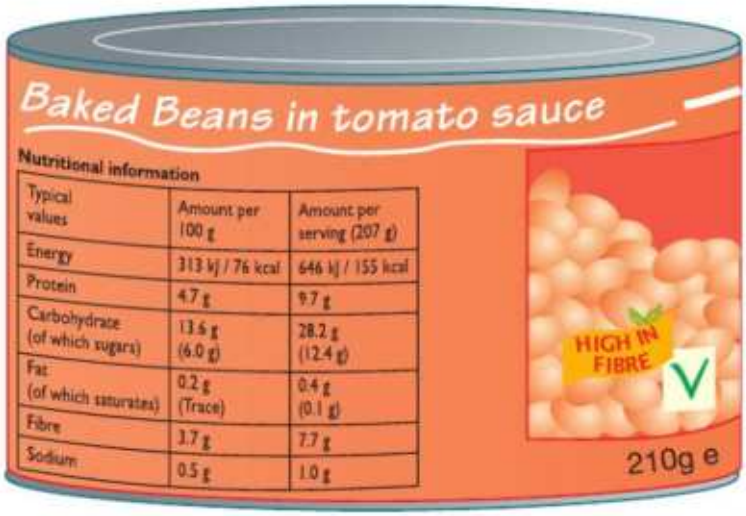
The test for protein is sometimes called the 'biuret' test, after the coloured compound that is formed.

A little protein, such as powdered egg white (albumen), is placed in a test tube and about 2 cm depth of water added. The tube is shaken to mix the powder with the water. An equal volume of dilute (5%) potassium hydroxide solution is added and the tube shaken again. Finally two drops of 1% copper sulfate solution are added. A purple colour develops. (Sometimes these two solutions are supplied already mixed together as 'biuret solution'.)

▼ PRACTICAL: TEST FOR LIPID

Fats and oils are insoluble in water, but will dissolve in ethanol (alcohol). The test for lipid uses this fact.

A pipette is used to place one drop of olive oil in the bottom of a test tube. About 2 cm depth of ethanol is added, and the tube is shaken to dissolve the oil. The solution is poured into a test tube that is about three-quarters full with cold water. A white cloudy layer forms on the top of the water. The white layer is caused by the ethanol dissolving in the water and leaving the lipid behind as a suspension of tiny droplets, called an emulsion.



▲ Figure 4.11 Food packaging is labelled with the proportions of different food types that it contains, along with its energy content. The energy in units called kilocalories (kcal) is also shown, but scientists no longer use this old-fashioned unit.

ENERGY FROM FOOD

Some foods contain more energy than others. It depends on the proportions of carbohydrate, lipid and protein that they contain. Their energy content is measured in kilojoules (kJ). If a gram of carbohydrate is fully oxidised, it produces about 17 kJ, whereas a gram of lipid yields over twice as much as this (39 kJ). Protein can produce about 18 kJ per gram. If you look on a food label, it usually shows the energy content of the food, along with the amounts of different nutrients that it contains (Figure 4.11).

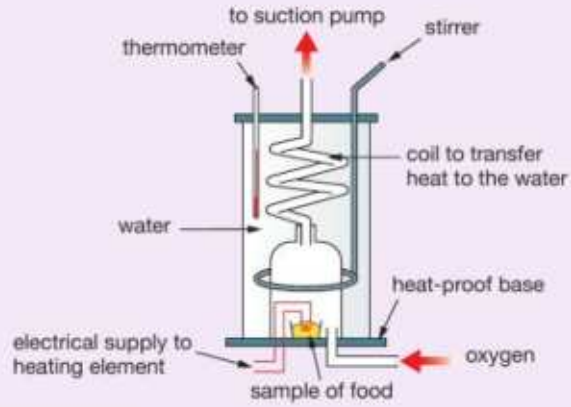
Foods with a high percentage of lipid, such as butter or nuts, contain a large amount of energy. Others, like fruits and vegetables, which are mainly composed of water, have a much lower energy content (Table 4.3).

Table 4.3 Energy content of some common foods

Food	kJ per 100g	Food	kJ per 100g
margarine	3200	white bread	1060
butter	3120	chips	990
peanuts	2400	grilled beef steak	930
samosa	2400	fried cod	850
chocolate	2300	roast chicken	770
Cheddar cheese	1700	boiled potatoes	340
table sugar	1650	milk	270
cornflakes	1530	baked beans	270
rice	1500	yoghurt	200
spaghetti	1450	boiled cabbage	60
fried beefburger	1100	lettuce	40

EXTENSION WORK

Food scientists measure the amount of energy in a sample of food by burning it in a calorimeter (Figure 4.12). The calorimeter is filled with oxygen, to make sure that the food will burn easily. A heating filament carrying an electrical current ignites the food. The energy given out by the burning food is measured by using it to heat up water flowing through a coil in the calorimeter.



▶ Figure 4.12 A food calorimeter

If you have samples of food that will easily burn in air, you can measure the energy in them by a similar method, using the heat from the burning food to warm up water in a test tube.

Table 4.4 The daily energy needs of different types of people.

Age/sex/occupation of person	Energy needed per day / kJ
newborn baby	2000
child aged 2	5000
child aged 6	7500
girl aged 12–14	9000
boy aged 12–14	11000
girl aged 15–17	9000
boy aged 15–17	12000
female office worker	9500
male office worker	10500
heavy manual worker	15000
pregnant woman	10000
breast-feeding woman	11300

Even while you are asleep you need a supply of energy – in order to keep warm, for your heart to keep beating, to allow messages to be sent through your nerves, and for other body functions. However, the energy you need at other times depends on the physical work you do. The total amount of energy that a person needs to keep healthy depends on their age and body size, and also on the amount of activity they do. Table 4.4 shows some examples of how much energy is needed each day by people of different age, sex and occupation.

Remember that these are approximate figures, and they are averages. Generally, the greater a person's weight, the more energy that person needs. This is why men, with a greater average body mass, need more energy than women. The energy needs of a pregnant woman are increased, mainly because of the extra weight that she has to carry. A heavy manual worker, such as a labourer, needs extra energy for increased muscle activity.

It is not only the recommended energy requirements that vary with age, sex and pregnancy, but also the *content* of the diet. For instance, during pregnancy a woman may need extra iron or calcium in her diet, for the growth of the fetus. In younger women, the blood loss during menstruation (periods) can result in anaemia, producing a need for extra iron in the diet.

DIGESTION

Food, such as a piece of bread, contains carbohydrates, lipids and proteins, but they are not the same carbohydrates, lipids and proteins as in our tissues. The components of the bread must first be broken down into their 'building blocks' before they can be absorbed through the wall of the gut. This process is called **digestion**. The digested molecules – sugars, fatty acids, glycerol and amino acids – along with minerals, vitamins and water, can then be carried around the body in the blood. When they reach the tissues they are reassembled into the molecules that make up our cells.

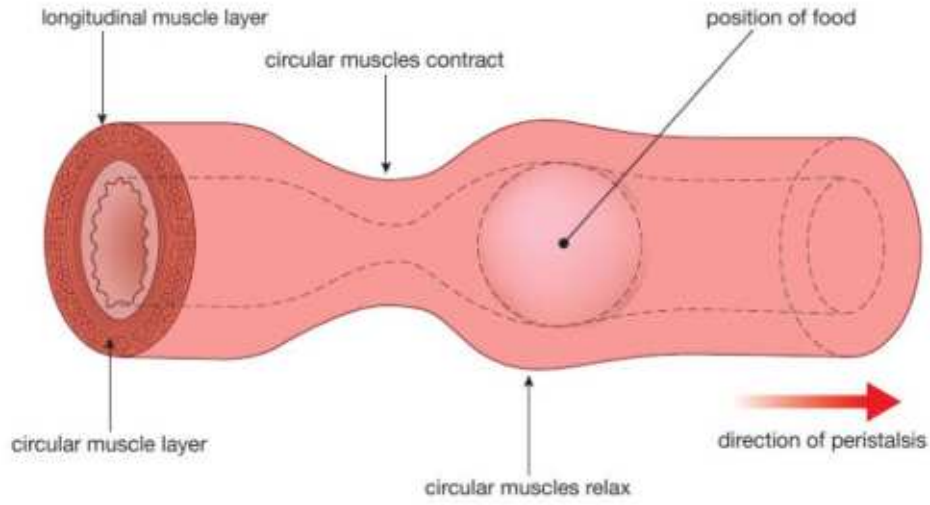
HINT

A good definition of digestion is: 'Digestion is the chemical and mechanical breakdown of food. It converts large insoluble molecules into small soluble molecules, which can be absorbed into the blood.'

Digestion is speeded up by **enzymes**, which are biological catalysts (see Chapter 1). Although most enzymes stay inside cells, the digestive enzymes are made by the tissues and glands in the gut and pass out of cells – on to the gut contents where they act on the food. This *chemical* digestion is helped by *mechanical* digestion. Mechanical digestion is the physical breakdown of food. The most obvious place where this happens is in the mouth, where the teeth bite and chew the food, cutting it into smaller pieces that have a larger surface area. This means that enzymes can act on the food more quickly. Other parts of the gut also help with mechanical digestion. For example, muscles in the wall of the stomach contract to churn up the food while it is being chemically digested.

PERISTALSIS

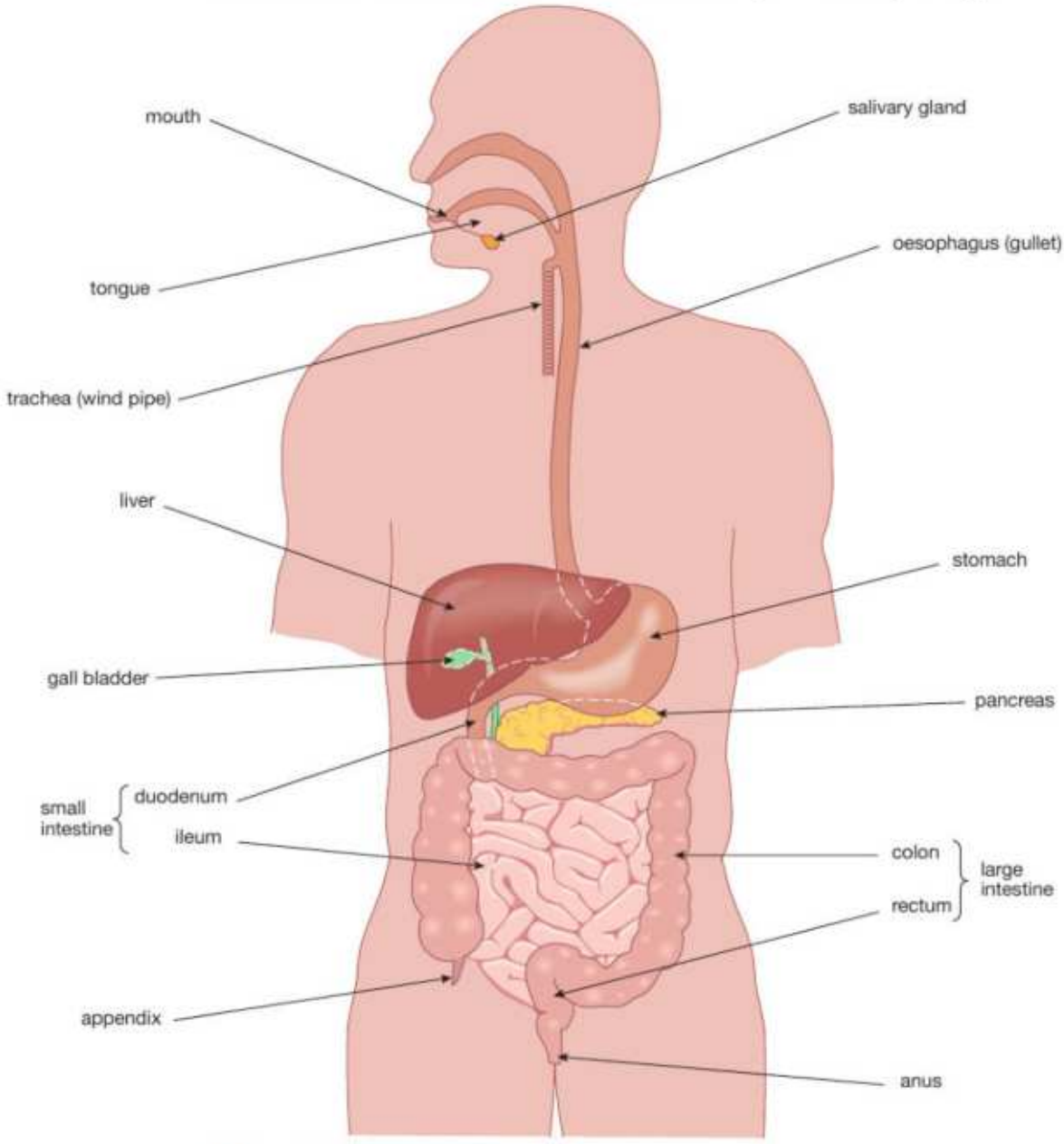
Muscles are also responsible for moving the food along the gut. The walls of the intestine contain two layers of muscles. One layer has fibres arranged in rings around the gut. This is the circular muscle layer. The other has fibres running along the length of the gut, and is called the longitudinal muscle layer. Together these two layers act to push the food along. When the circular muscles contract and the longitudinal muscles relax, the gut is made narrower. When the opposite happens, i.e. the longitudinal muscles contract and the circular muscles relax, the gut becomes wider. Waves of muscle contraction like this pass along the gut, pushing the food along, rather like squeezing toothpaste from a tube. This is called **peristalsis** (Figure 4.13). It means that movement of food in the gut doesn't depend on gravity – we can still eat standing on our heads!



▲ Figure 4.13 Peristalsis: contraction of circular muscles behind the food narrows the gut, pushing the food along. When the circular muscles are contracted, the longitudinal ones are relaxed, and vice versa.

THE DIGESTIVE SYSTEM

Figure 4.14 shows a simplified diagram of the human digestive system. It is simplified so that you can see the order of the organs along the gut. The real gut is much longer than this, and coiled up so that it fills the whole space of the abdomen. Overall, its length in an adult is about 8 m. This gives plenty of time for the food to be broken down and absorbed as it passes through the gut.



▲ Figure 4.14 The human digestive system

The mouth, stomach and the first part of the small intestine (called the **duodenum**) all break down the food using enzymes, either made in the gut wall itself, or by glands such as the **pancreas**. Digestion continues in the last part of the small intestine (the **ileum**) and it is here that the digested food is absorbed. The last part of the gut, the large intestine, is mainly concerned with absorbing water out of the remains, and storing the waste products (**faeces**) before they are removed from the body.

The three main classes of food are broken down by three classes of enzymes. Carbohydrates are digested by enzymes called **carbohydrases**. Proteins are acted upon by **proteases**, and enzymes called **lipases** break down lipids. Some of the places in the gut where these enzymes are made are shown in Table 4.5.

KEY POINT

Amylase digests starch into maltose. Amylase is the enzyme, starch is the substrate and maltose is the product.

Digestion begins in the mouth. **Saliva** helps moisten the food and contains the enzyme **amylase**, which starts the breakdown of starch. The chewed lump of food, mixed with saliva, then passes along the **oesophagus** (gullet) to the stomach.

Table 4.5 Some of the enzymes that digest food in the human gut. The substances shown in bold are the end products of digestion that can be absorbed from the gut into the blood.

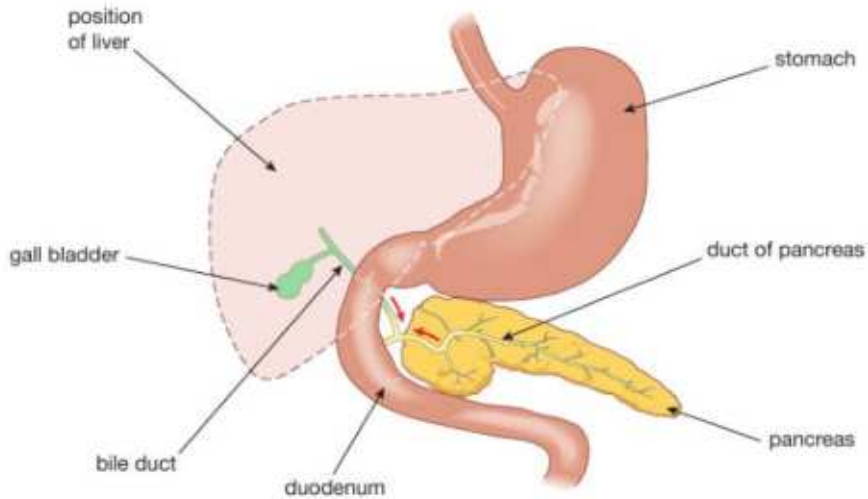
Class of enzyme	Examples	Digestive action	Source of enzyme	Where it acts in the gut
carbohydrases	amylase amylase maltase	starch → maltose[1] starch → maltose maltose → **glucose**	salivary glands pancreas wall of small intestine	mouth small intestine small intestine
proteases	pepsin trypsin peptidases	proteins → peptides[2] proteins → peptides peptides → **amino acids**	stomach wall pancreas wall of small intestine	stomach small intestine small intestine
lipases	lipase	lipids → **glycerol** and **fatty acids**	pancreas	small intestine

[1]Maltose is a disaccharide made of two glucose molecules joined together.

[2]Peptides are short chains of amino acids.

The food is held in the stomach for several hours, while initial digestion of protein takes place. The stomach wall secretes hydrochloric acid, so the stomach contents are strongly acidic. This has a very important function. It kills bacteria that are taken into the gut along with the food, helping to protect us from food poisoning. The protease enzyme that is made in the stomach, called **pepsin**, has to be able to work in these acidic conditions, and has an optimum pH value of about 2. This is unusually low – most enzymes work best at near neutral conditions (see Chapter 1).

The semi-digested food is held back in the stomach by a ring of muscle at the outlet of the stomach, called a **sphincter muscle**. When this relaxes, it releases the food into the first part of the small intestine, called the duodenum (Figure 4.15).



▲ Figure 4.15 The first part of the small intestine, the duodenum, receives digestive juices from the liver and pancreas through tubes called ducts.



▲ Figure 4.16 Bile turns fats into an emulsion of tiny droplets for easier digestion.

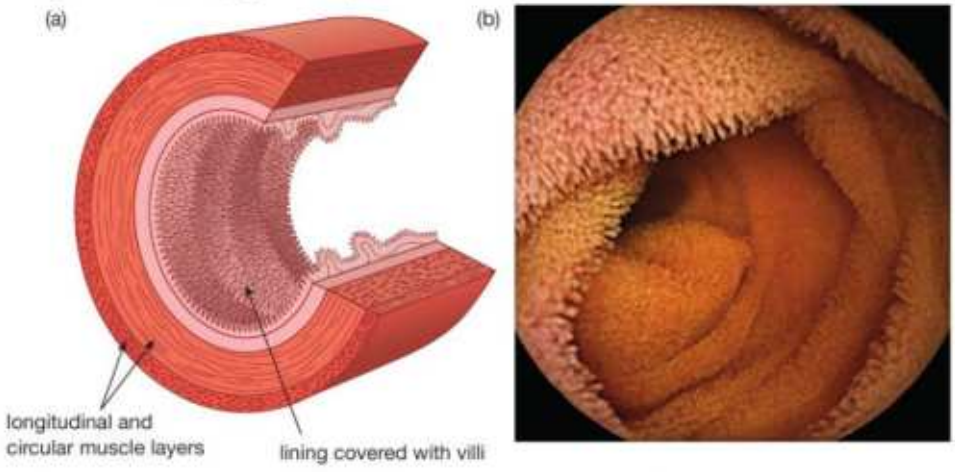
Several digestive enzymes are added to the food in the duodenum. These are made by the pancreas, and digest starch, proteins and lipids (Table 4.5). As well as this, the **liver** makes a digestive juice called **bile**. Bile is a green liquid that is stored in the **gall bladder** and passes down the **bile duct** on to the food. Bile does not contain enzymes, but has another important function. It turns any large lipid globules in the food into an emulsion of tiny droplets (Figure 4.16). This increases the surface area of the lipid, so that lipase enzymes can break it down more easily.

Bile and pancreatic juice have another function. They are both alkaline. The mixture of semi-digested food and enzymes coming from the stomach is acidic, and needs to be neutralised by the addition of alkali before it continues on its way through the gut.

As the food continues along the intestine, more enzymes are added, until the parts of the food that can be digested have been fully broken down into soluble end products, which can be absorbed. This is the role of the last part of the small intestine, the ileum.

ABSORPTION IN THE ILEUM

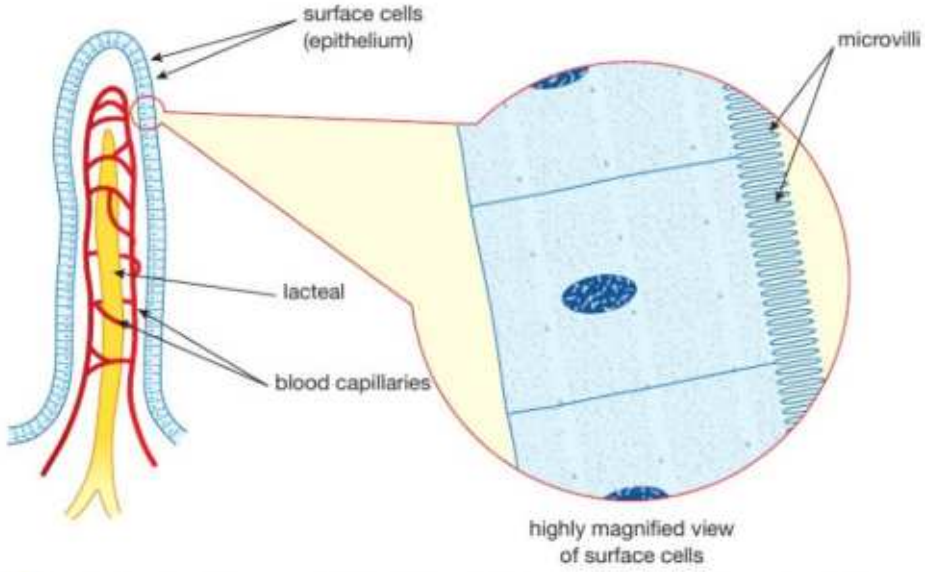
The ileum is highly adapted to absorb the digested food. The lining of the ileum has a very large surface area, which means that it can quickly and efficiently absorb the soluble products of digestion into the blood. The length of the intestine helps to provide a large surface area, and this is aided by folds in its lining, but the greatest increase in area is due to tiny projections from the lining, called **villi** (Figure 4.17).



▲ Figure 4.17 (a) The inside lining of the ileum is adapted to absorb digested food by the presence of millions of tiny villi. (b) Photo of the inside a patient's ileum, taken using a camera attached to an endoscope. You can see thousands of tiny villi covering the lining.

The singular of villi is 'villus'. Each villus is only about 1–2 mm long, but there are millions of them, so that the total area of the lining is thought to be about 300 m^2. This provides a massive area in contact with the digested food. As well as this, high-powered microscopy has revealed that the surface cells of each villus themselves have hundreds of minute projections, called **microvilli**, which increase the surface area for absorption even more (Figure 4.18).

Each villus contains a network of blood capillaries. Most of the digested food enters these blood vessels, but the products of fat digestion, as well as tiny fat droplets, enter a tube in the middle of the villus, called a **lacteal**. The lacteals form part of the body's lymphatic system, which transports a liquid called lymph. This lymph eventually drains into the blood system too.



▲ Figure 4.18 Each villus contains blood vessels and a lacteal, which absorb the products of digestion. The surface cells of the villus are covered with microvilli, which further increase the surface area for absorption.

The surface of a villus is made of a single layer of cells called an epithelium. This means that there is only a short distance between the digested food in the ileum and the blood capillaries making it easier for the products of digestion to diffuse through and enter the blood. The epithelium cells contain many mitochondria, which supply the energy needed for active transport of some substances.

In addition each villus contains muscle fibres which contract to move the villus. The villi are in constant motion, keeping them in contact with the contents of the ileum and maintaining a steep concentration gradient for diffusion of the products of digestion.

The blood vessels from the ileum join up to form a large blood vessel called the **hepatic portal vein**, which leads to the liver (see Chapter 5). The liver acts rather like a food processing factory, breaking some molecules down, and building up and storing others. For example, glucose from carbohydrate digestion is converted into glycogen and stored in the liver. Later, the glycogen can be converted back into glucose when the body needs it (see Chapter 7).

The digested food molecules are distributed around the body by the blood system (see Chapter 5). The soluble food molecules are absorbed from the blood into cells of tissues, and are used to build new parts of cells. This is called assimilation.

KEY POINT

Removal of faeces by the body is sometimes incorrectly called excretion. Excretion is a word that only applies to materials that are the waste products of cells of the body, such as carbon dioxide. Faeces are not products of cell metabolism – they consist of waste that has passed through the gut and left the body via the anus, without entering the cells. The correct name for this process is egestion.

THE LARGE INTESTINE – ELIMINATION OF WASTE

By the time that the contents of the gut have reached the end of the small intestine, most of the digested food, as well as most of the water, has been absorbed. The waste material consists mainly of cellulose (fibre) and other indigestible remains, water, dead and living bacteria and cells lost from the lining of the gut. The function of the first part of the large intestine, called the **colon**, is to absorb most of the remaining water from the contents, leaving a semi-solid waste material called faeces. This is stored in the **rectum**, until expelled out of the body through the **anus**.

CHAPTER QUESTIONS

More questions on food and digestion can be found at the end of Unit 2 on page 116.

SKILLS CRITICAL THINKING

1 Which of the following organic molecules contains carbon, hydrogen, oxygen and nitrogen?

A glycogen
B lipid
C cellulose
D protein

2 Which of the following substances would give a positive test when boiled with Benedict's solution?

A fructose
B lipid
C starch
D protein

3 Which of the following statements about digestion is *not* correct?

A Digestion produces fatty acids and glycerol
B Digestion converts insoluble molecules into soluble molecules
C Digestion changes proteins into amino acids
D Digestion releases energy from food

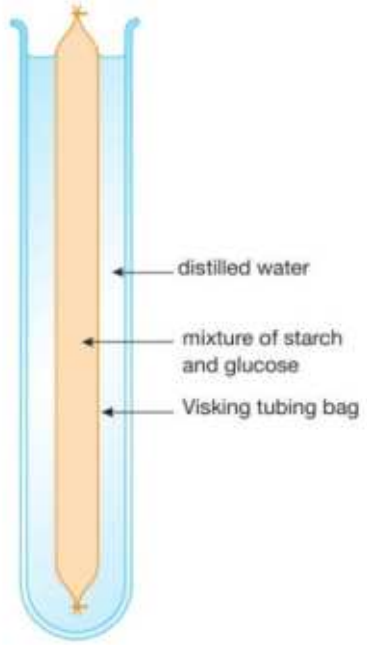
4 Which of the following organs does *not* produce digestive enzymes?

A salivary gland
B gall bladder
C stomach
D pancreas

SKILLS EXECUTIVE FUNCTION

5 The diagram shows an experiment that was set up as a model to show why food needs to be digested.

The Visking tubing acts as a model of the small intestine because it has tiny holes in it that some molecules can pass through. The tubing was left in the boiling tube for an hour, then the water in the tube was tested for starch and glucose.



a Describe how you would test the water for starch, and for glucose. What would the results be for a 'positive' test in each case?

SKILLS REASONING

b The tests showed that glucose was present in the water, but starch was not. Explain why.

c If the tubing takes the place of the intestine, what part of the body does the water in the boiling tube represent?

SKILLS CRITICAL THINKING

d What does 'digested' mean?

SKILLS DECISION MAKING

6 A student carried out an experiment to find out the best conditions for the enzyme pepsin to digest protein. For the protein, she used egg white powder, which forms a cloudy white suspension in water. The table below shows how the four tubes were set up.

Tube	Contents
A	5 cm^3 egg white suspension, 2 cm^3 pepsin, 3 drops of dilute acid. Tube kept at 37 °C
B	5 cm^3 egg white suspension, 2 cm^3 distilled water, 3 drops of dilute acid. Tube kept at 37 °C
C	5 cm^3 egg white suspension, 2 cm^3 pepsin, 3 drops of dilute acid. Tube kept at 20 °C
D	5 cm^3 egg white suspension, 2 cm^3 pepsin, 3 drops of dilute alkali. Tube kept at 37 °C

The tubes were left for 2 hours and the results were then observed. Tubes B, C and D were still cloudy. Tube A had gone clear.

a Three tubes were kept at 37 °C. Why was this temperature chosen?

SKILLS REASONING

b Explain what had happened to the protein in tube A.

c Why did tube D stay cloudy?

SKILLS CRITICAL THINKING

d Tube B is called a **Control**. Explain what this means.

SKILLS REASONING

e Tube C was left for another 3 hours. Gradually it started to clear. Explain why digestion of the protein happened more slowly in this tube.

SKILLS CRITICAL THINKING

f The lining of the stomach secretes hydrochloric acid. Explain the function of this.

g When the stomach contents pass into the duodenum, they are still acidic. How are they neutralised?

7 Copy and complete the following table of digestive enzymes.

Enzyme	Food on which it acts	Products
amylase		
trypsin		
		fatty acids and glycerol

8 Describe four adaptations of the small intestine (ileum) that allow it to absorb digested food efficiently.

SKILLS CRITICAL THINKING, CREATIVITY

9 Bread is made mainly of starch, protein and lipid. Imagine a piece of bread about to start its journey through the human gut. Describe what happens to the bread as it passes through the mouth, stomach, duodenum, ileum and colon. Explain how the bread is moved along the gut. Your description should be illustrated by two or three simplified diagrams.

5 BLOOD AND CIRCULATION

Large, multicellular animals need a circulatory system to transport substances to and from the cells of the body. This chapter looks at the structure and function of the circulatory systems of humans and other animals, the composition of mammalian blood, and disorders associated with the heart and circulation.

LEARNING OBJECTIVES

- Understand why simple unicellular organisms can rely on diffusion for movement of substances in and out of the cell
- Understand the need for a transport system in multicellular organisms
- Understand the general structure of the circulation system, including the blood vessels to and from the heart and lungs, liver and kidneys
- Describe the structure of the heart and how it functions
- Understand how factors may increase the risk of developing coronary heart disease
- Explain how the heart rate changes during exercise and under the influence of adrenaline
- Understand how the structures of arteries, veins and capillaries relate to their functions
- Describe the composition of blood: red blood cells, white blood cells, platelets and plasma
- Understand the role of plasma in the transport of carbon dioxide, digested food, urea, hormones and heat energy
- Understand how the adaptations of red blood cells make them suitable for the transport of oxygen, including shape, the absence of a nucleus and the presence of haemoglobin
- Understand how the immune system responds to infection using white blood cells, illustrated by phagocytes ingesting pathogens and lymphocytes releasing antibodies specific to the pathogen

THE NEED FOR CIRCULATORY SYSTEMS

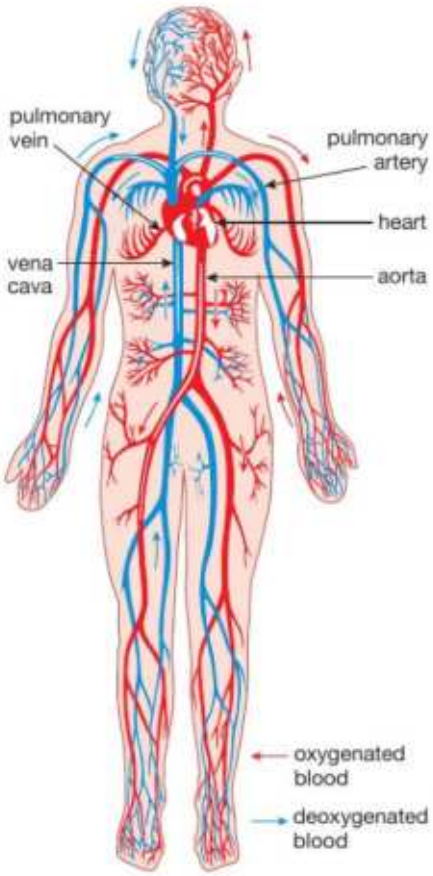
Figure 5.1 shows the circulatory system of a mammal.

Blood is pumped around a closed circuit made up of the heart and blood vessels. As it travels around the body, it collects materials from some places and unloads them in others. In mammals, blood transports:

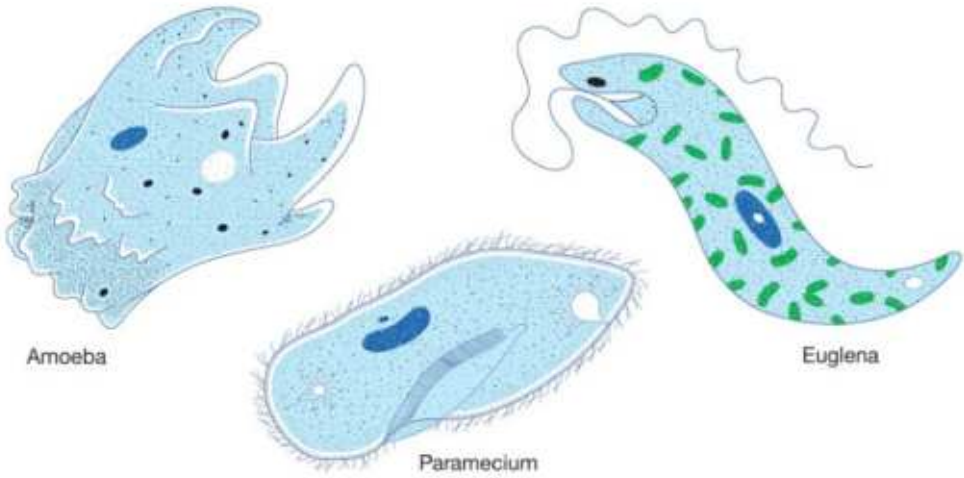
- oxygen from the lungs to all other parts of the body
- carbon dioxide from all parts of the body to the lungs
- nutrients from the gut to all parts of the body
- urea from the liver to the kidneys.

Hormones, antibodies and many other substances are also transported by the blood. It also distributes heat around the body.

Single-celled organisms, like the ones shown in Figure 5.2, do not have circulatory systems.



▲ Figure 5.1 The human circulatory system.



▲ Figure 5.2 Unicellular organisms do not have circulatory systems.

There is no circulatory system to carry materials around the very small 'bodies' of these single-celled organisms. Materials can easily move around the cell without a special system. There is no need for lungs or gills to obtain oxygen from the environment either. Single-celled organisms obtain oxygen by diffusion through the surface membrane of the cell. The rest of the cell then uses the oxygen. The area of the cell's surface determines how much oxygen the organism can get (the supply rate), and the volume of the cell determines how much oxygen the organism uses (the demand rate).

The ratio of supply to demand can be written as: $\frac{\text{surface area}}{\text{volume}}$

This is called the 'surface area to volume ratio' and it is affected by the size of an organism (see Chapter 1, Activity 4). Single-celled organisms have a high surface area to volume ratio. Their cell surface membrane has a large enough area to supply all the oxygen that their volume demands. In larger animals, the surface area to volume ratio is lower.

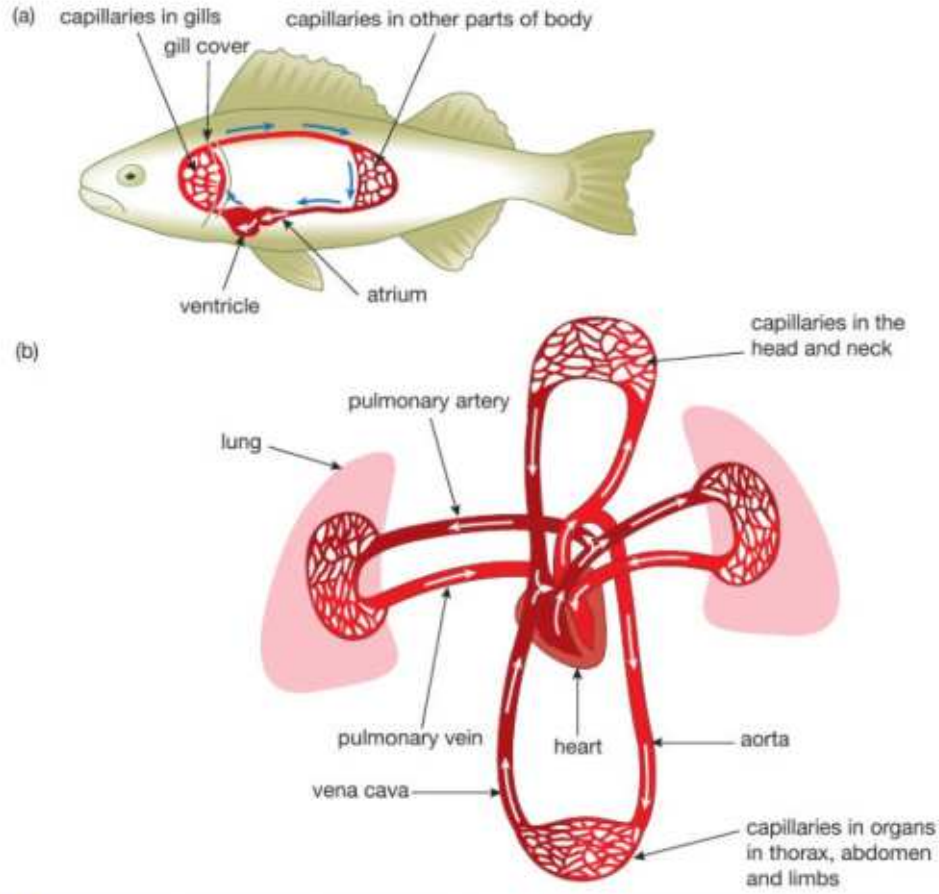
Large animals cannot get all the oxygen they need through their surface (even if the body surface would allow it to pass through) – there just isn't enough surface to supply all that volume. To overcome this problem, large organisms have evolved special gas exchange organs and circulatory systems. The gills of fish and the lungs of mammals are linked to a circulatory system that carries oxygen to all parts of the body. The same idea applies to obtaining nutrients – the gut obtains nutrients from food and the circulatory system distributes the nutrients around the body.

THE CIRCULATORY SYSTEMS OF DIFFERENT ANIMALS

One of the main functions of a circulatory system in animals is to transport oxygen. Blood is pumped to a gas exchange organ to load oxygen. It is then pumped to other parts of the body where it unloads the oxygen. There are two main types of circulatory systems in animals.

- In a **single circulatory** system the blood is pumped from the heart to the gas exchange organ and then directly to the rest of the body.
- In a **double circulatory** system the blood is pumped from the heart to the gas exchange organ, back to the heart and then to the rest of the body.

Figure 5.3 shows the difference between these systems.



▲ Figure 5.3 (a) The single circulatory system of a fish. The blood passes through the heart only once in a complete circuit of the body. (b) The double circulatory system of a human (and other mammals). The blood passes through the heart twice in one complete circuit of the body.

There are two parts to a double circulatory system:

- The **pulmonary circulation**. Deoxygenated blood leaves the heart through the pulmonary arteries, and is circulated through the lungs, where it becomes oxygenated. The oxygenated blood returns to the heart through the pulmonary veins.
- The **systemic circulation**. Oxygenated blood leaves the heart through the aorta and is circulated through all other parts of the body, where it unloads its oxygen. Deoxygenated blood returns to the heart through the vena cava.

A double circulatory system is more efficient than a single circulatory system. The heart pumps the blood twice, so higher pressures can be maintained. The blood travels more quickly to organs. In the single circulatory system of a fish, blood loses pressure as it passes through the gills. It then travels more slowly to the other organs.

The human circulatory system comprises:

- the heart – this is a pump
- blood vessels – these carry the blood around the body; **arteries** carry blood away from the heart and towards other organs, **veins** carry blood towards the heart and away from other organs and **capillaries** carry blood through organs, linking the arteries and veins
- blood – the transport medium.

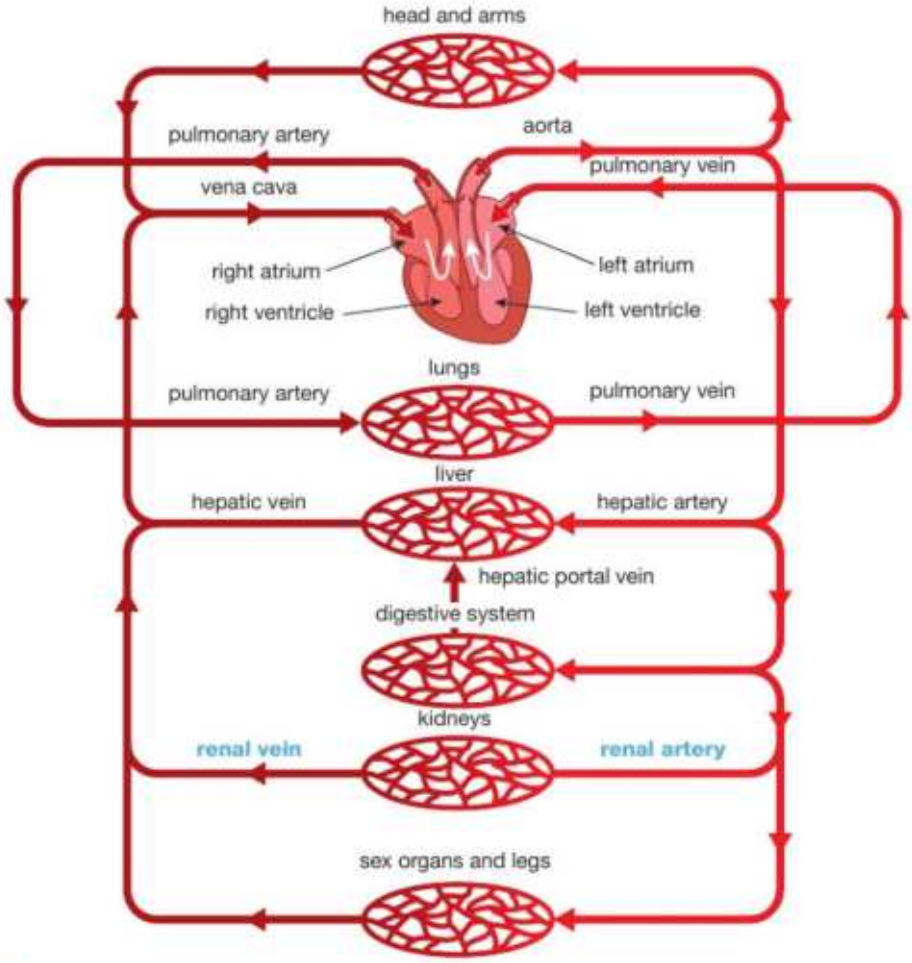
Figure 5.4 shows the main blood vessels in the human circulatory system.

KEY POINT

'Pulmonary' means 'relating to the lungs'.

DID YOU KNOW?

There are actually two vena cavae (the plural of vena cava). One brings blood back from the head and arms and the other returns blood from the rest of the body (see Figure 5.4).



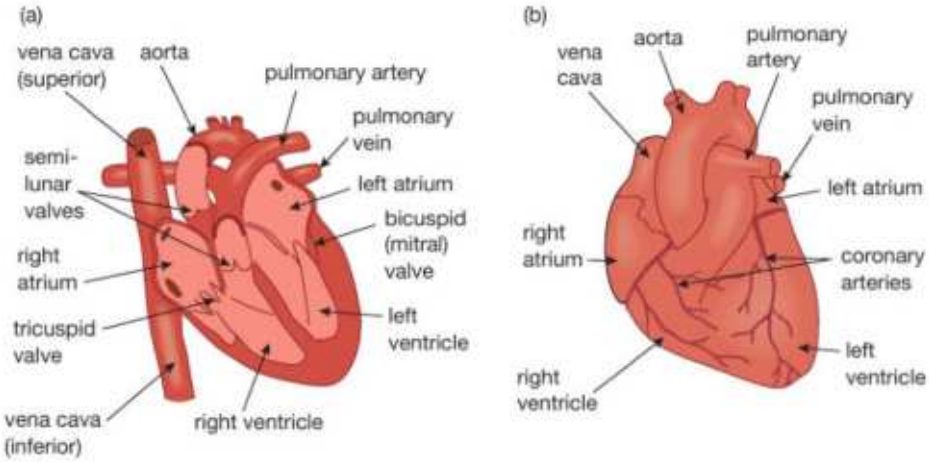
▲ Figure 5.4 The main components of the human circulatory system

THE STRUCTURE AND FUNCTION OF THE HUMAN HEART

The human heart is a pump (Figure 5.5). It pumps blood around the body at different speeds and at different pressures according to the body's needs.

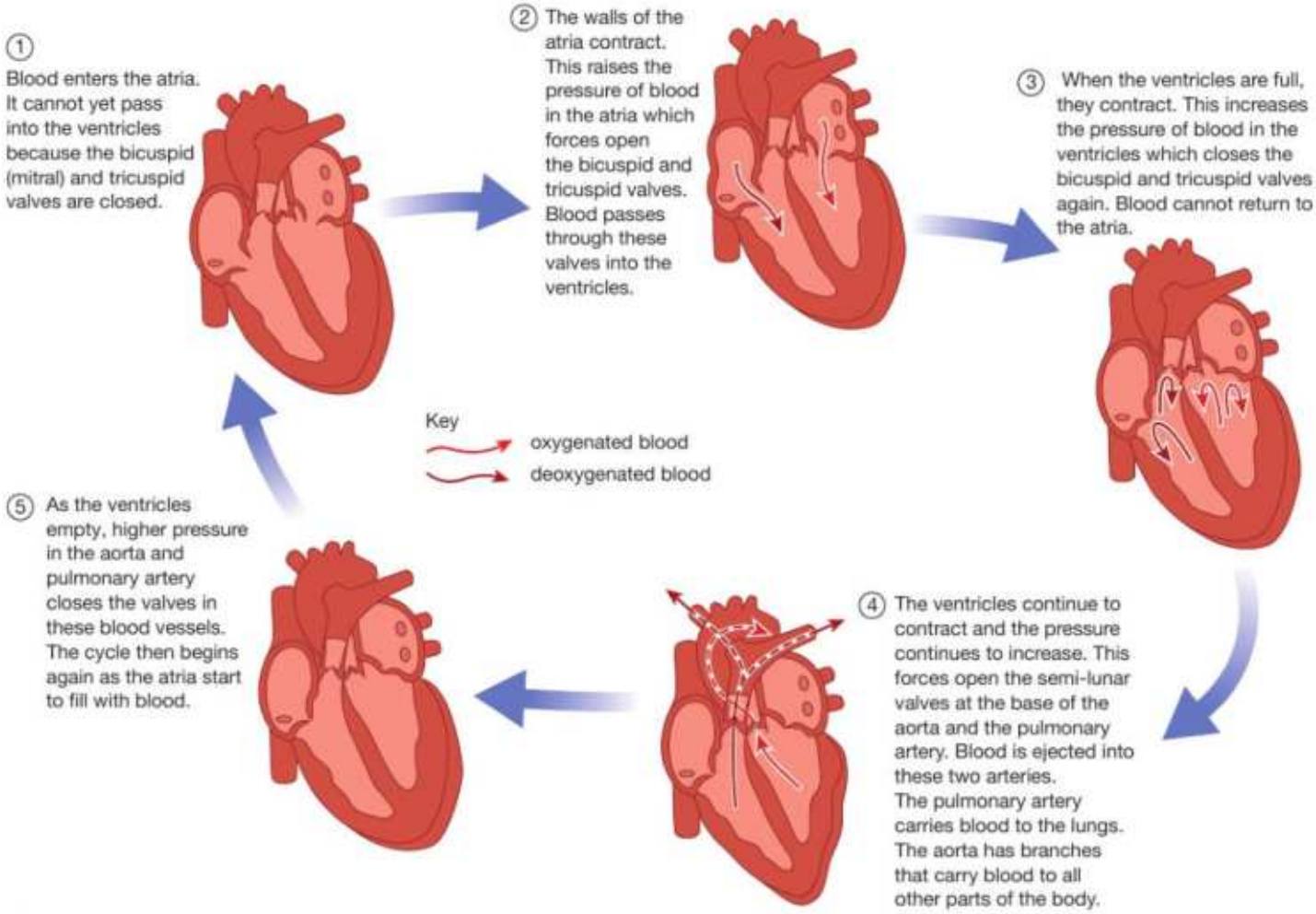
DID YOU KNOW?
'Cardiac' means 'related to the heart'.

DID YOU KNOW?
The **bicuspid** (mitral) and **tricuspid valves** are both sometimes called atrioventricular valves, as each controls the passage of blood from an atrium to a ventricle.



▲ Figure 5.5 The human heart: (a) vertical section; (b) external view

Blood is moved through the heart by a series of contractions and relaxations of the muscle in the walls of the four chambers. These events form the **cardiac cycle**. The main stages are illustrated in Figure 5.6.



▲ Figure 5.6 The cardiac cycle.

HINT

Note that during the cardiac cycle both atria contract at the same time (and then relax). After this both ventricles contract at the same time (and then relax). Students are sometimes confused about this, and think that one ventricle contracts, followed by the other.

KEY POINT

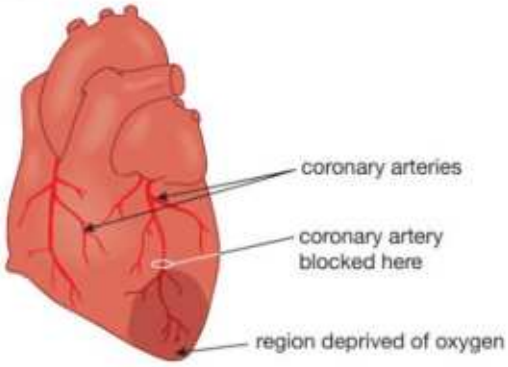
Cardiac muscle is unlike any other muscle in our bodies. It never gets fatigued ('tired') like skeletal muscle. On average, cardiac muscle fibres contract and then relax again about 70 times a minute. In a lifetime of 70 years, this special muscle will contract over two billion times – without taking a rest!

The structure of the heart is adapted to its function in several ways:

- It is divided into a left side and a right side by a wall of muscle called the septum. The right **ventricle** pumps blood only to the lungs while the left ventricle pumps blood to all other parts of the body. This requires much more pressure, which is why the wall of the left ventricle is much thicker than that of the right ventricle.
- Valves ensure that blood can flow only in one direction through the heart.
- The walls of the **atria** are thin. They can be stretched to receive blood as it returns to the heart but can contract with enough force to push blood through the bicuspid and tricuspid valves into the ventricles.
- The walls of the heart are made of **cardiac muscle**, which can contract and then relax continuously without becoming fatigued.
- The cardiac muscle has its own blood supply – the coronary circulation. Blood reaches the muscle via **coronary arteries**. These carry blood to capillaries that supply the heart muscle with oxygen and nutrients. Blood is returned to the right atrium via **coronary veins**.

CORONARY HEART DISEASE

The coronary arteries are among the narrowest in the body. They are easily blocked by a build-up of fatty substances (including **cholesterol**) in their walls. This can cut off the blood supply to an area of cardiac muscle. The affected muscle can no longer receive oxygen and glucose, so it cannot respire and release energy. This means it is unable to contract, resulting in a heart attack. This is called **coronary heart disease (CHD)**. It can lead to severe health problems and is often fatal.



▲ Figure 5.7 A blockage of a coronary artery cuts off the blood supply to part of the heart muscle.

A number of factors make coronary heart disease more likely:

- heredity – some people inherit a tendency to develop coronary heart disease
- high blood pressure – puts more strain on the heart
- diet – eating large amounts of saturated fat is likely to raise cholesterol levels
- smoking – raises blood pressure and makes blood clots more likely to form
- stress – raises blood pressure
- lack of exercise – regular exercise helps to reduce blood pressure and strengthens the heart.

HEART RATE

Normally the heart beats about 70 times a minute, but this can change according to the needs of the body. When we exercise, muscles must release more energy. They need an increased supply of oxygen for aerobic respiration (see Chapter 1). To deliver the extra oxygen, both the number of beats per minute (heart rate) and the volume of blood pumped with each beat (called stroke volume) increase.

When we are angry or afraid our heart rate again increases. The increased output supplies extra blood to the muscles, enabling them to release extra energy through aerobic respiration. This allows us to fight or run away and is called the 'fight or flight' response. It is triggered by **secretion** of the hormone **adrenaline** from the adrenal glands (see Chapter 7).

When we sleep, our heart rate decreases as all our organs are working more slowly. They need to release less energy and so need less oxygen.

These changes in the heart rate are controlled by nerve impulses from a part of the brain called the **medulla** (Figure 5.8). When we start to

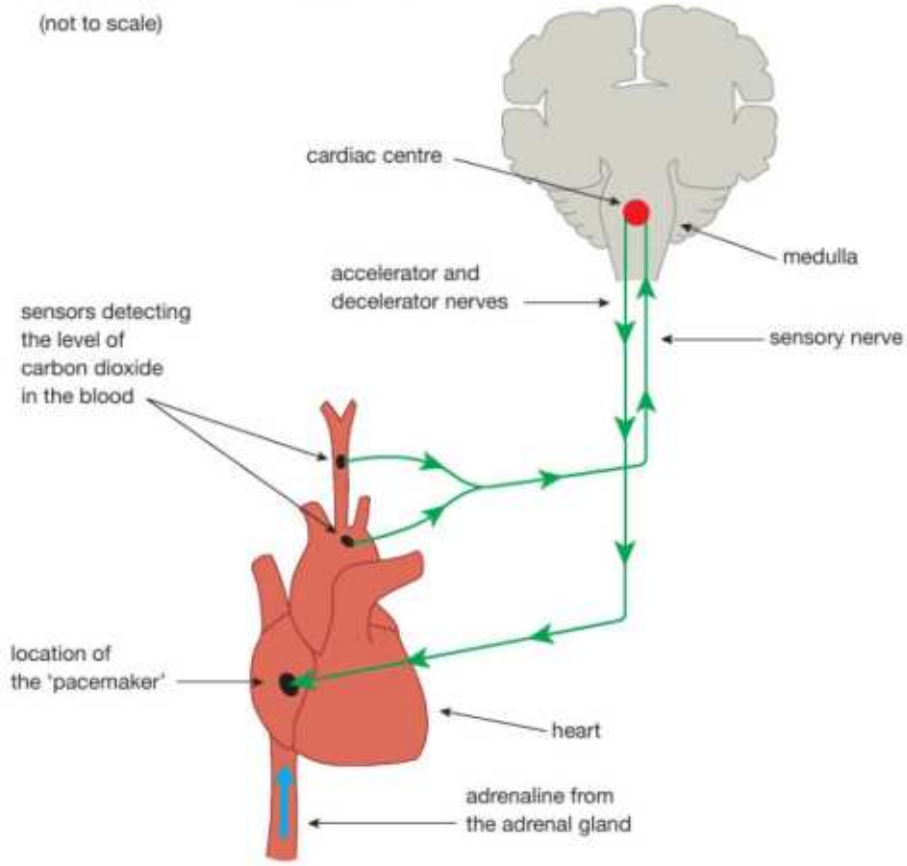
DID YOU KNOW?

Have you noticed a 'hollow' or 'fluttering' feeling in your stomach when you are anxious? It happens because blood that would normally flow to your stomach and intestines has been diverted to the muscles to allow the 'fight or flight' response.

exercise, our muscles produce more carbon dioxide in aerobic respiration. Receptors in the aorta and the carotid **artery** (the artery leading to the head) detect this increase. They send electrical signals called nerve impulses through the sensory nerve to the medulla. The medulla responds by sending nerve impulses along the accelerator nerve. When carbon dioxide production returns to normal, the medulla receives fewer impulses. It responds by sending nerve impulses along a decelerator nerve.

KEY POINT

The precise region of the medulla that controls heart functions is called the **cardiac centre**.



▲ Figure 5.8 How the heart rate is controlled.

The accelerator nerve increases the heart rate. It also causes the heart to beat with more force and so increases blood pressure. The decelerator nerve decreases the heart rate. It also reduces the force of the contractions. Blood pressure then returns to normal.

These controls are both examples of **reflex actions** (see Chapter 6).

ARTERIES, VEINS AND CAPILLARIES

Arteries carry blood from the heart to the organs of the body. This arterial blood is pumped out by the ventricles at a high pressure. Elastic tissue in the walls of the arteries allows them to stretch and recoil (spring back into shape), maintaining the high blood pressure. A thick muscular wall helps control the flow of blood by dilating (widening) or constricting (narrowing) the vessels.

Veins carry blood from organs back towards the heart. The pressure of this venous blood is much lower than that in the arteries. It puts very little pressure on the walls of the veins, so they can be thinner than those of arteries, and contain less elastic tissue and muscle. Figure 5.9 shows the structure of a typical artery and a typical vein with the same diameter.

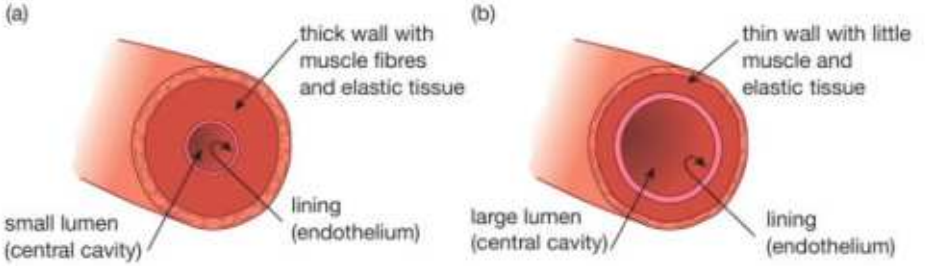
EXTENSION WORK

Arterioles are small arteries. They carry blood into organs from arteries. Their structure is similar to the larger arteries, but they have a larger proportion of muscle fibres in their walls. They are also supplied with nerve endings in their walls and so can be made to dilate (become wider) or constrict (become narrower) to allow more or less blood into the organ.

If *all* the arterioles constrict, it is harder for blood to pass through them – there is more resistance. This increases blood pressure. Prolonged stress can cause arterioles to constrict and so increase blood pressure.

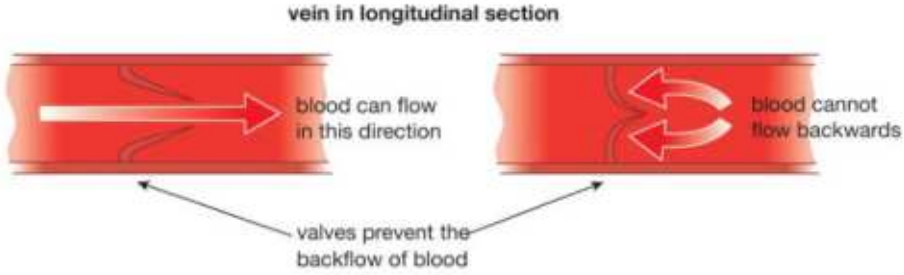
KEY POINT

All arteries carry oxygenated blood (blood containing a lot of oxygen) except the pulmonary artery and the umbilical artery of an unborn baby. All veins carry deoxygenated blood (blood containing less oxygen) except the pulmonary vein and umbilical vein.



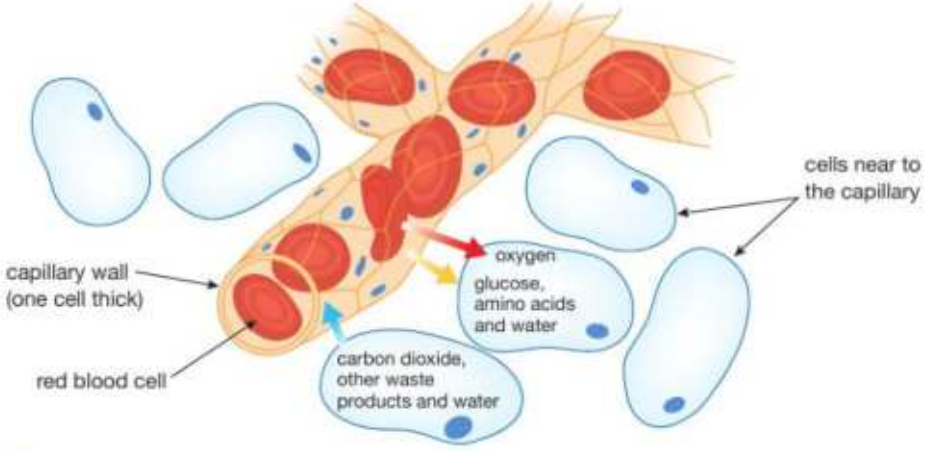
▲ Figure 5.9 The structure of (a) an artery and (b) a vein as seen in cross section.

Veins also have **semilunar** (half-moon shaped) **valves**, which prevent the backflow of blood. The action of these valves is explained in Figure 5.10.

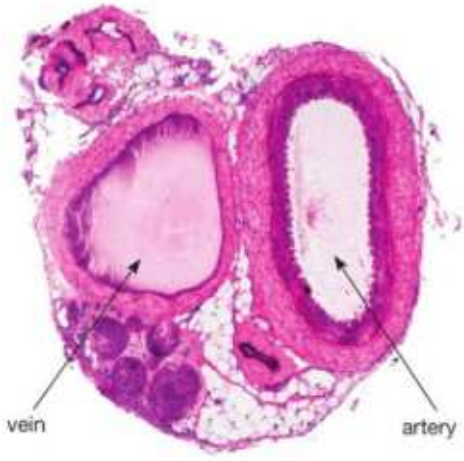


▲ Figure 5.10 The action of semilunar valves in veins

Capillaries carry blood through organs, bringing the blood close to every cell in the organ. Substances are transferred between the blood in the capillary and the cells. To do this, capillaries must be small enough to 'fit' between cells, and allow materials to pass through their walls easily. Figure 5.11 shows the structure of a capillary and how exchange of substances takes place between the capillary and nearby cells. The walls of capillaries are one cell thick, providing a short distance for diffusion of materials into and out of the blood. Red blood cells just fit through the tiny diameter of capillaries, so they are close to the capillary wall. This means that there is a short distance for oxygen to diffuse. Figure 5.12 shows a photograph of a cross-section through an artery and a vein.



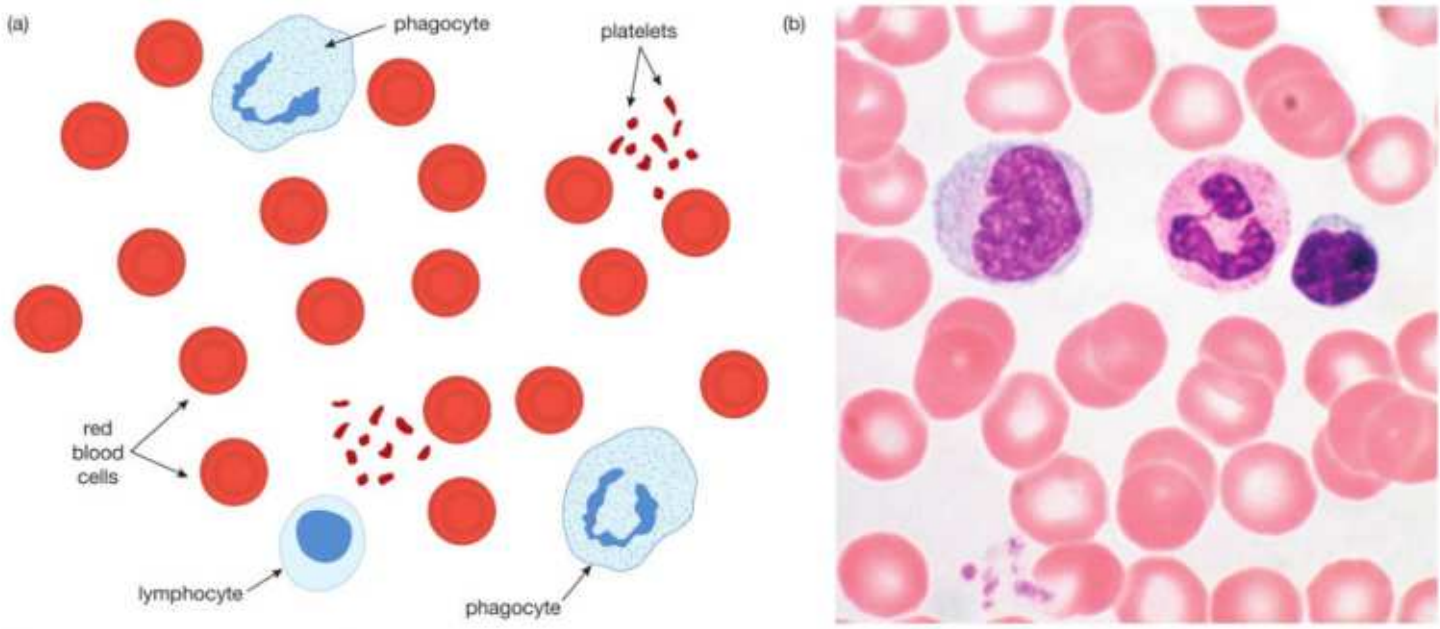
▲ Figure 5.11 How capillaries exchange materials with cells



▲ Figure 5.12 The lumen of the artery is the same size as the lumen of the vein – but note the difference in the thickness of the walls of these two vessels.

THE COMPOSITION OF BLOOD

Blood is a lot more than just a red liquid flowing through your arteries and veins! In fact, blood is a complex tissue. Figure 5.13 illustrates the main types of cells found in blood.



▲ Figure 5.13 The different types of blood cells. (a) Diagram of the different cells. (b) A blood smear seen through a light microscope. The smear shows many red blood cells and three different kinds of white blood cell.

The different parts of blood have different functions. These are described in Table 5.1.

Table 5.1 Functions of the different components of blood.

COMPONENT OF BLOOD	DESCRIPTION OF COMPONENT	FUNCTION OF COMPONENT
plasma	liquid part of blood: mainly water	carries the blood cells around the body; carries dissolved nutrients, hormones, carbon dioxide and urea; also distributes heat around the body
red blood cells (erythrocytes)	biconcave, disc-like cells with no nucleus; millions in each mm^3 of blood	transport of oxygen – contain mainly haemoglobin, which loads oxygen in the lungs and unloads it in other regions of the body
WHITE BLOOD CELLS:		
lymphocytes	about the same size as red cells with a large spherical nucleus	produce antibodies to destroy microorganisms – some lymphocytes persist in our blood after infection and give us immunity to specific diseases
phagocytes	much larger than red cells, with a large spherical or lobed nucleus	digest and destroy bacteria and other microorganisms that have infected our bodies
platelets	the smallest cells – are really fragments of other cells	release chemicals to make blood clot when we cut ourselves

RED BLOOD CELLS

The red blood cells or **erythrocytes** are highly specialised cells made in the bone marrow. They have a limited life span of about 100 days after which time they are destroyed in the spleen. They have only one function – to transport oxygen. Several features enable them to carry out this function very efficiently.

Red blood cells contain **haemoglobin**. This is an iron-containing protein that associates (combines) with oxygen to form **oxyhaemoglobin** when there is a high concentration of oxygen in the surroundings. We say that the red blood cell is loading oxygen. When the concentration of oxygen is low, oxyhaemoglobin turns back into haemoglobin and the red blood cell unloads its oxygen.

As red blood cells pass through the lungs, they load oxygen. As they pass through active tissues they unload oxygen.

$$\text{haemoglobin} + \text{oxygen} \underset{\text{in the tissues}}{\overset{\text{in the lungs}}{\rightleftharpoons}} \text{oxyhaemoglobin}$$

Red blood cells do not contain a nucleus. It is lost during their development in the bone marrow. This means that more haemoglobin can be packed into each red blood cell so more oxygen can be transported. Their biconcave shape allows efficient exchange of oxygen in and out of the cell. Each red blood cell has a high surface area to volume ratio, giving a large area for diffusion. The thin shape of the cell results in a short diffusion distance to the centre of the cell.

WHITE BLOOD CELLS

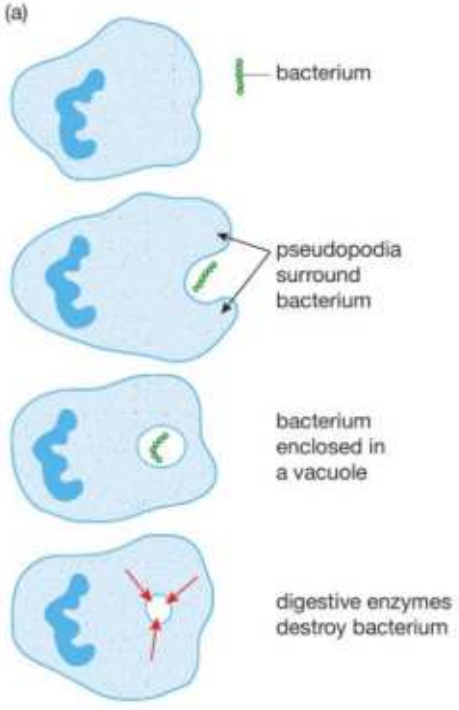
There are several types of white blood cell. Their main role is to protect the body against invasion by disease-causing microorganisms (pathogens), such as bacteria and viruses. They do this in two main ways: **phagocytosis** and production of **antibodies**.

About 70% of white blood cells can ingest (take in) microorganisms such as bacteria. This is called phagocytosis, and the cells are **phagocytes**. They do this by changing their shape, producing extensions of their cytoplasm, called pseudopodia. The pseudopodia surround and enclose the microorganism in a vacuole. Once it is inside, the phagocyte secretes enzymes into the vacuole to break the microorganism down (Figure 5.14). Phagocytosis means 'cell eating' – you can see why it is called this.

Approximately 25% of white blood cells are **lymphocytes**. Their function is to make chemicals called antibodies. Antibodies are soluble proteins that pass into the plasma. Pathogens such as bacteria and viruses have chemical 'markers' on their surfaces, which the antibodies recognise. These markers are called **antigens**. The antibodies stick to the surface antigens and destroy the pathogen. They do this in a number of ways, for example by:

- causing bacteria to stick together, so that phagocytes can ingest them more easily
- acting as a 'label' on the pathogen, so that it is more easily recognised by a phagocyte
- causing bacterial cells to burst open
- neutralising poisons (toxins) produced by pathogens.

The production of antibodies following the first exposure to a foreign antigen is called the primary **immune response**.



▲ Figure 5.14 (a) Phagocytosis by a white blood cell. (b) A phagocyte engulfing a pathogenic microorganism (a species of yeast).

CHAPTER QUESTIONS

More questions on blood and circulation can be found at the end of Unit 2 on page 116.

SKILLS CRITICAL THINKING

1 After a period of exercise, which blood vessel will contain the highest concentration of carbon dioxide?

A aorta
B vena cava
C hepatic artery
D pulmonary vein

2 When the right ventricle contracts, to which of the following structures does the blood flow next?

A aorta
B left atrium
C pulmonary artery
D left ventricle

3 The diagram below shows sections through three blood vessels (not drawn to scale).



Which row in the table shows the correct names of vessels X, Y and Z?

	X	Y	Z
A	vein	capillary	artery
B	artery	capillary	vein
C	vein	artery	capillary
D	capillary	vein	artery

4 Which component of the blood makes antibodies?

A red blood cells
B white blood cells
C plasma
D platelets

5 Some animals have a single circulatory system, some have a double circulatory system and some organisms have no circulatory system at all.

a Name one type of animal with a single circulatory system and one type of animal with a double circulatory system.

b Explain:

i the difference between single and double circulatory systems

SKILLS REASONING

ii why a double circulatory system is more efficient than a single circulatory system.

c Explain why single-celled organisms do not need a circulatory system.

SKILLS CRITICAL THINKING

6 Blood transports oxygen and carbon dioxide around the body. Oxygen is transported by the red blood cells.

a Give three ways in which a red blood cell is adapted to its function of transporting oxygen.

b Describe how oxygen:

i enters a red blood cell from the alveoli in the lungs

ii passes from a red blood cell to an actively respiring muscle cell.

c Describe how carbon dioxide is transported around the body.

SKILLS REASONING

7 Blood is carried around the body in arteries, veins and capillaries.

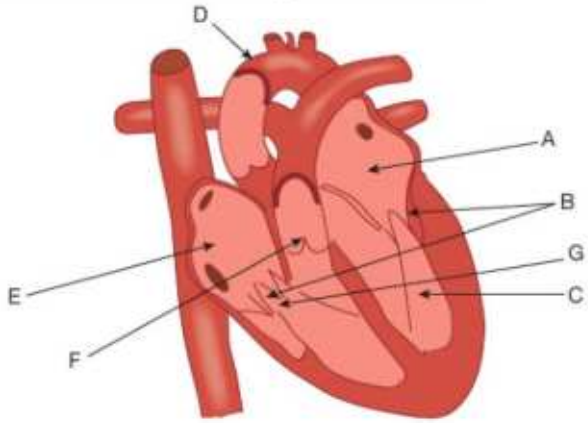
a Describe two ways in which the structure of an artery is adapted to its function.

b Describe three differences between arteries and veins.

c Describe two ways in which the structure of a capillary is adapted to its function.

SKILLS ANALYSIS

8 The diagram shows a section through a human heart.



a Name the structures labelled A, B, C, D and E.

SKILLS CRITICAL THINKING

b What is the importance of the structures labelled B and F?

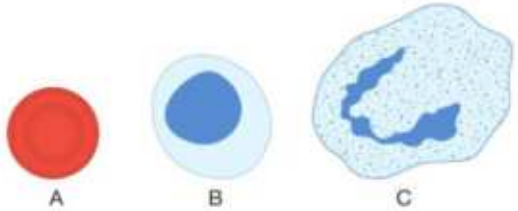
SKILLS ANALYSIS

c Which letters represent the chambers of the heart to which blood returns:

i from the lungs

ii from all the other organs of the body?

9 The diagram shows three types of cells found in human blood.



a Giving a reason for each answer, identify the blood cell which:

i transports oxygen around the body

ii produces antibodies to destroy bacteria

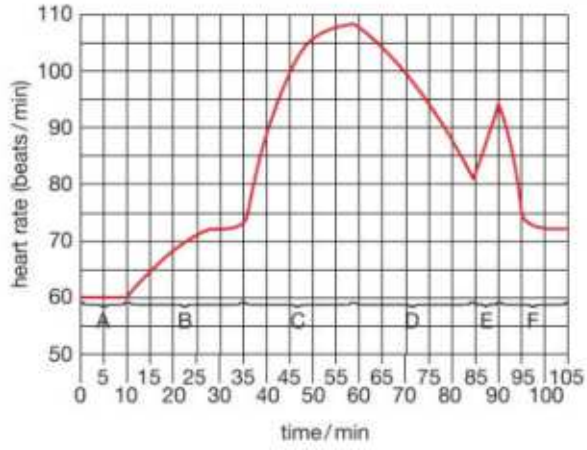
iii engulfs and digests bacteria.

SKILLS CRITICAL THINKING

b Name one other component of blood found in the plasma and state its function.

SKILLS ANALYSIS

10 The graph shows changes in a person's heart rate over a period of time.



Giving reasons for your answers, give the letter of the time period when the person was:

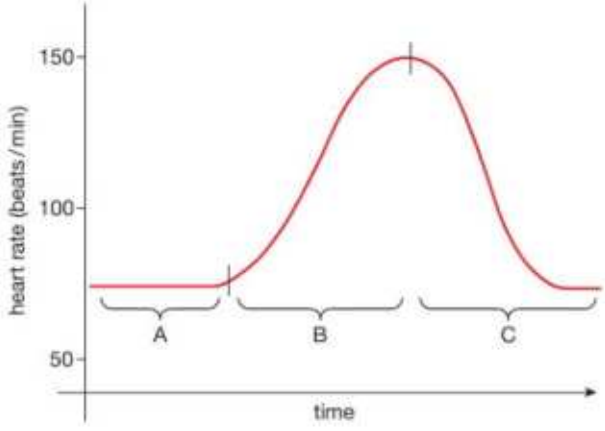
a running

b frightened by a sudden loud noise

c sleeping

d waking.

11 The graph shows the changes that take place in heart rate before, during and after a period of exercise.



a Describe and explain the heart rates found:

i at rest, before exercise (period A)

ii as the person commences the exercise (period B)

iii as the person recovers from the exercise (period C).

SKILLS REASONING

b How can the recovery period (period C) be used to assess a person's fitness?

6 COORDINATION

In the body 'coordination' means making things happen at the right time by linking up different body activities. Humans and other animals have two organ systems which do this. The first is the nervous system, which is the subject of this chapter. The second is the hormone or endocrine system, which is dealt with in Chapter 7.

LEARNING OBJECTIVES

- Understand how organisms are able to respond to changes in their environment
- Understand that a coordinated response requires a stimulus, a receptor and an effector
- Understand that the central nervous system consists of the brain and spinal cord and is linked to sense organs by nerves
- Describe how the nervous system controls responses
- Understand how stimulation of receptors in the sense organs sends electrical impulses along nerves into and out of the central nervous system, resulting in rapid responses
- Describe the structure and function of the eye as a receptor
- Understand the function of the eye in focusing on near and distant objects, and in responding to changes in light intensity
- Describe the structure and functioning of a simple reflex arc, illustrated by the withdrawal of a finger from a hot object
- Understand the role of neurotransmitters at synapses

STIMULUS AND RESPONSE

Suppose you are walking along when you see a football coming at high speed towards your head. If your nerves are working properly, you will probably move or duck quickly to avoid contact. Imagine another situation where you are very hungry, and you smell food cooking. Your mouth might begin to 'water', in other words secrete saliva.

KEY POINT

The surroundings outside the body are called the *external* environment. The inside of the body is known as the *internal* environment. The body also responds to changes in its internal environment, such as temperature and blood glucose levels. You will read about these responses in Chapters 7 and 8.

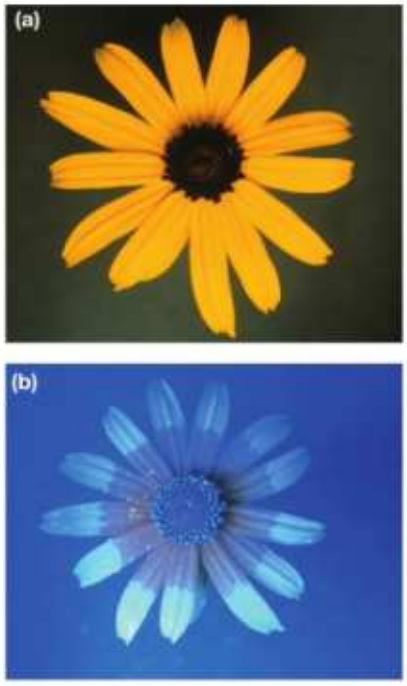
Each of these situations is an example of a **stimulus** and a **response**. A *stimulus* is a change in an animal's surroundings, and a *response* is a reaction to that change. In the first example, the approaching ball was the stimulus, and your movement to avoid it hitting you was the response. The change in your environment was detected by your eyes, which are an example of a **receptor** organ. The response was brought about by contraction of muscles, which are a type of **effector** organ (they produce an effect). The nervous system links the two, and is an example of a coordination system. A summary of the sequence of events is:

stimulus → receptor → coordination → effector → response

In the second example, the receptor for the smell of food was the nose, and the response was the secretion of saliva from glands. Glands secrete (release) chemical substances, and they are the second type of effector organ. Again, the link between the stimulus and the response is the nervous system. The information in the nerve cells is transmitted in the form of tiny electrical signals called **nerve impulses**.

DID YOU KNOW?

Some animals can detect changes in their environment that are not sensed by humans. Insects such as bees can see ultraviolet (UV) light. The wavelengths of UV are invisible to humans (Figure 6.1).



▲ Figure 6.1 This yellow flower (a) looks very different to a bee, which sees patterns on the petals reflecting UV light (b).

Some organisms can even detect the direction of magnetic fields. Many birds, such as pigeons, have a built-in compass in their brain, which they use for navigation. A species of bacterium can also do this, but as yet no one can explain why this might be an advantage to it!

RECEPTORS

The role of any receptor is to detect the stimulus by changing its energy into the electrical energy of the nerve impulses. For example, the eye converts light energy into nerve impulses, and the ear converts sound energy into nerve impulses (Table 6.1).

Table 6.1 Human receptors and the energy they receive.

Receptor	Type of energy received
eye (retina)	light
ear (organ of hearing)	sound
ear (organ of balance)	mechanical (kinetic)
tongue (taste buds)	chemical
nose (organ of smell)	chemical
skin (touch/pressure/pain receptors)	mechanical (kinetic)
skin (temperature receptors)	heat
muscle (stretch receptors)	mechanical (kinetic)

Notice how a 'sense' like touch is made up of several components. When we touch a warm surface we will be stimulating several types of receptor, including touch and temperature receptors, as well as stretch receptors in the muscles (see the section on skin in Chapter 8). As well as this, each sense detects different aspects of the energy it receives. For example, the ears don't just detect sounds, but different loudness and frequencies of sound, while the eye not only forms an image, but also detects brightness of light and in humans can tell the difference between different light wavelengths (colours). Senses tell us a great deal about changes in our environment.

THE CENTRAL NERVOUS SYSTEM

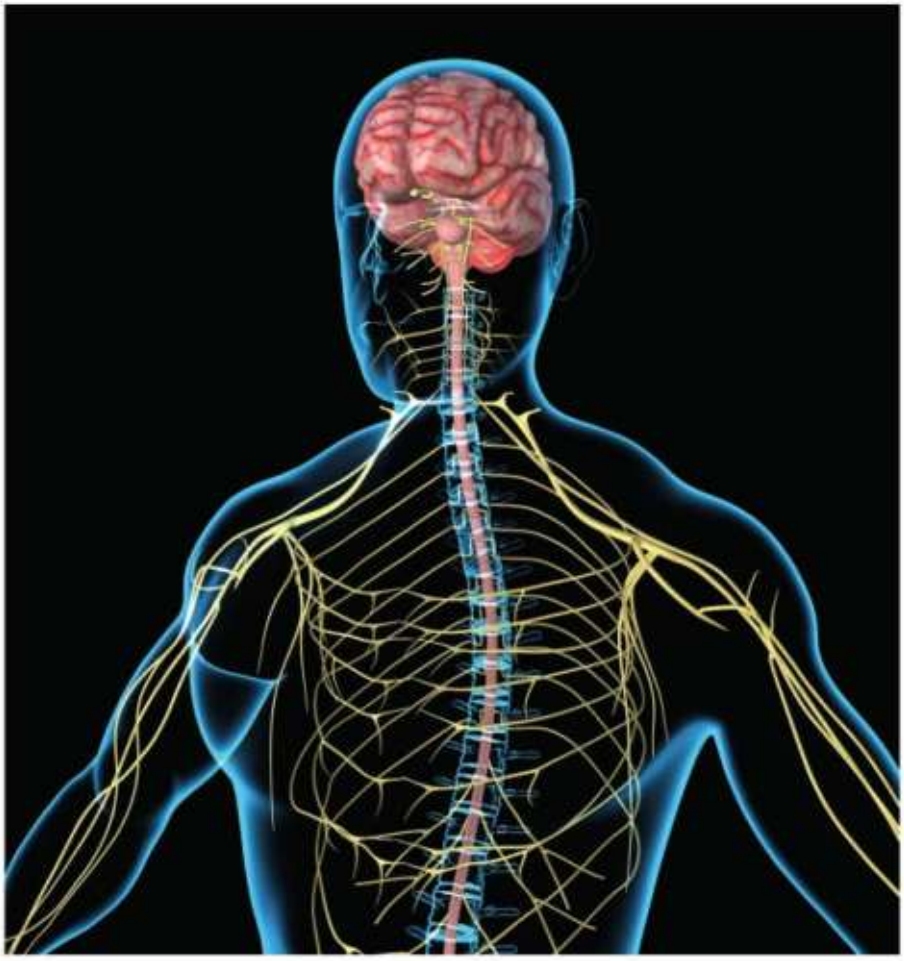
The biological name for a nerve cell is a **neurone**. The impulses that travel along a neurone are not an electric current, as in a wire. They are caused by movements of charged particles (ions) in and out of the neurone. Impulses travel at speeds between about 10 and 100 metres per second, which is much slower than an electric current, but fast enough to produce a rapid response (see the 'Looking ahead' feature at the end of this chapter).

Impulses from receptors pass along nerves containing **sensory neurones**, until they reach the brain and spinal cord. These two organs are together known as the **central nervous system**, or **CNS** (Figure 6.2).

Other nerves contain **motor neurones**, transmitting impulses to the muscles and glands. Some nerves contain only sensory or motor cells, while other nerves contain both – they are 'mixed'. A typical nerve contains thousands of individual neurones.

DID YOU KNOW?

The CNS is well protected by the skeleton. The brain is inside the skull or cranium (nerves connected to the brain are *cranial* nerves) and the spinal cord runs down the middle of the spinal column, passing through a hole in each vertebra. Nerves connected to the spinal cord are called *spinal* nerves.

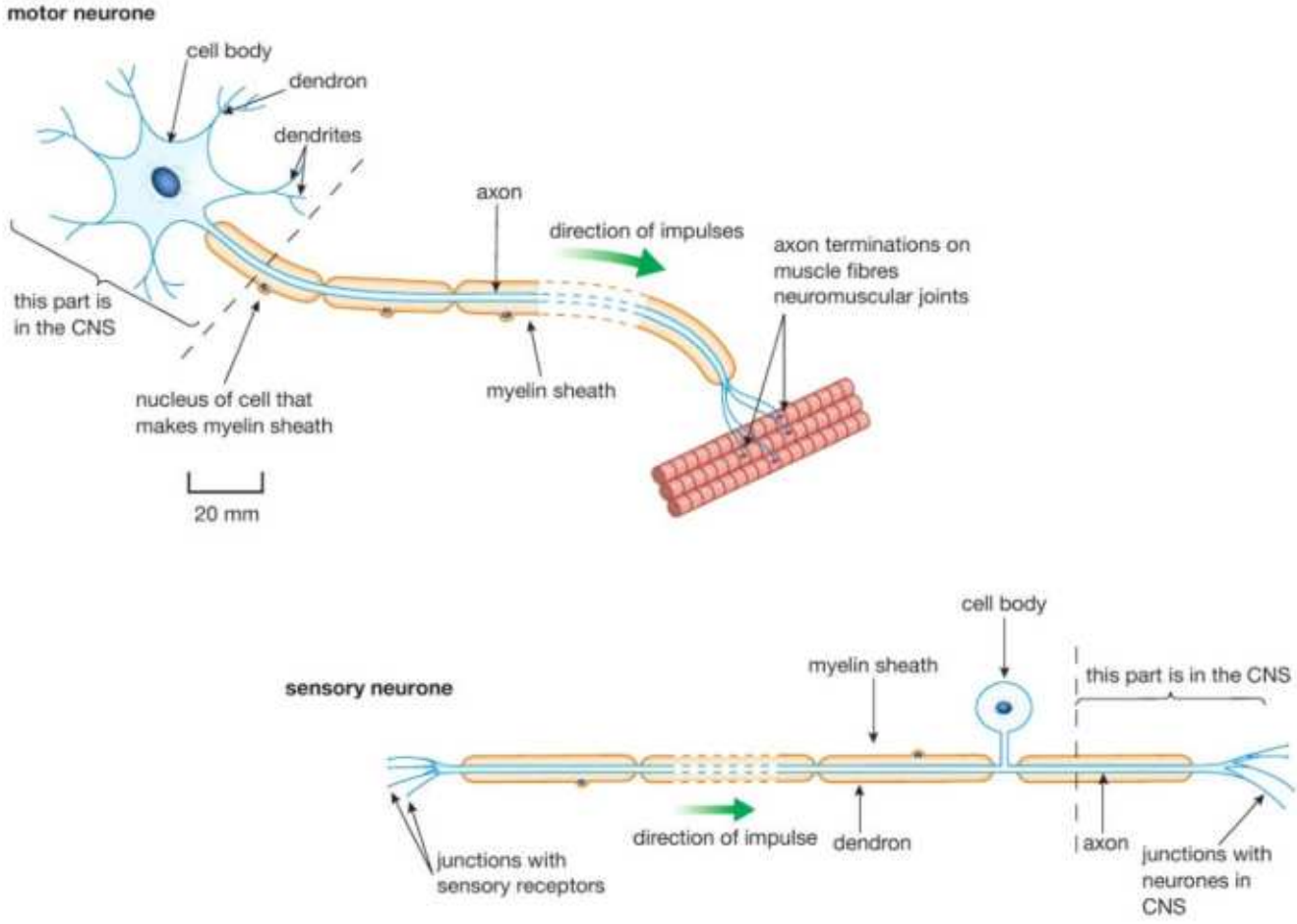


▲ Figure 6.2 The brain and spinal cord form the central nervous system. Cranial and spinal nerves lead to and from the CNS. The CNS sorts out information from the senses and sends messages to muscles.

THE STRUCTURE OF NEURONES

Both sensory and motor neurones can be very long. For example, a motor neurone leading from the CNS to the muscles in the finger has a fibre about a metre in length, which is 100 000 times the length of the cell body (Figure 6.3).

The cell body of a motor neurone is at one end of the fibre, in the CNS. The cell body has fine cytoplasmic extensions, called **dendrons**. These in turn form finer extensions, called **dendrites**. There can be junctions with other neurones on any part of the cell body, dendrons or dendrites. These junctions are called **synapses**. Later in this chapter we will deal with the importance of synapses in nerve pathways. One of the extensions from the motor neurone cell body is much longer than the other dendrons. This is the fibre that carries impulses to the effector organ, and is called the **axon**. At the end of the axon furthest from the cell body, it divides into many nerve endings. These fine branches of the axon connect with a muscle at a special sort of synapse called a **neuromuscular junction**. In this way impulses are carried from the CNS out to the muscle. The signals from nerve impulses are transmitted across the neuromuscular junction, causing the muscle fibres to contract. The axon is covered by a sheath made of a fatty material called myelin. The **myelin sheath** insulates the axon, preventing 'short circuits' with other axons, and also speeds up the conduction of the impulses. The sheath is formed by the membranes of special cells that wrap themselves around the axon as it develops.



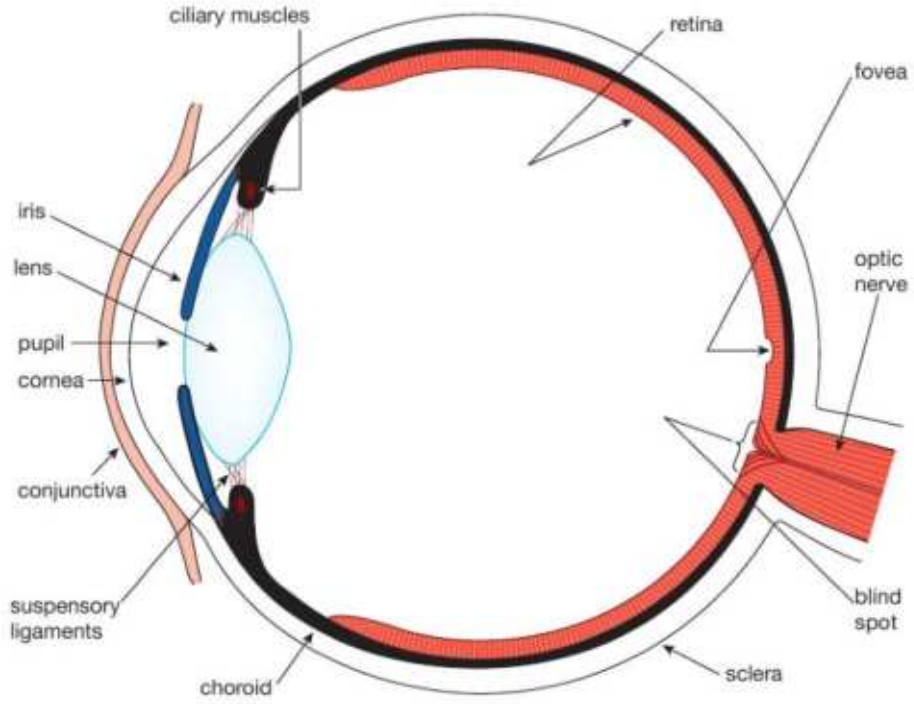
▲ Figure 6.3 The structure of motor and sensory neurones. The cell fibres (axon/dendron) are very long, which is indicated by the dashed sections.

A **sensory neurone** has a similar structure to the motor neurone, but the cell body is located on a side branch of the fibre, just outside the CNS. The fibre from the sensory receptor to the cell body is actually a dendron, while the fibre from the cell body to the CNS is a short axon. As with motor neurones, fibres of sensory neurones are often myelinated.

THE EYE

Many animals have eyes, but few show the complexity of the human eye. Simpler animals, such as snails, use their eyes to detect light but cannot form a proper image. Other animals, such as dogs, can form images but cannot distinguish colours. The human eye does all three. Of course it is not really the eye that 'sees' anything at all, but the brain that interprets the impulses from the eye. To find out how light from an object is converted into impulses representing an image, we need to look at the structure of this complex organ (Figure 6.4).

The tough outer coat of the eye is called the **sclera**, which is the visible, white part of the eye. At the front of the eye the sclera becomes a transparent 'window' called the **cornea**, which lets light into the eye. Behind the cornea is the coloured ring of tissue called the **iris**. In the middle of the iris is a hole called the **pupil**, which lets the light through. It is black because there is no light escaping from the inside of the eye.



▲ Figure 6.4 A horizontal section through the human eye

DID YOU KNOW?

The fact that the inverted image is seen the right way up by the brain makes the point that it is the brain which 'sees' things, not the eye. An interesting experiment was carried out to test this. Volunteers were made to wear special inverting goggles for long periods. These turned the view of their surroundings upside down. At first this completely disorientated them, and they found it difficult to make even simple coordinated movements. However, after a while their brains adapted, until the view through the goggles looked normal. In fact, when the volunteers removed the goggles, the world then looked upside down!

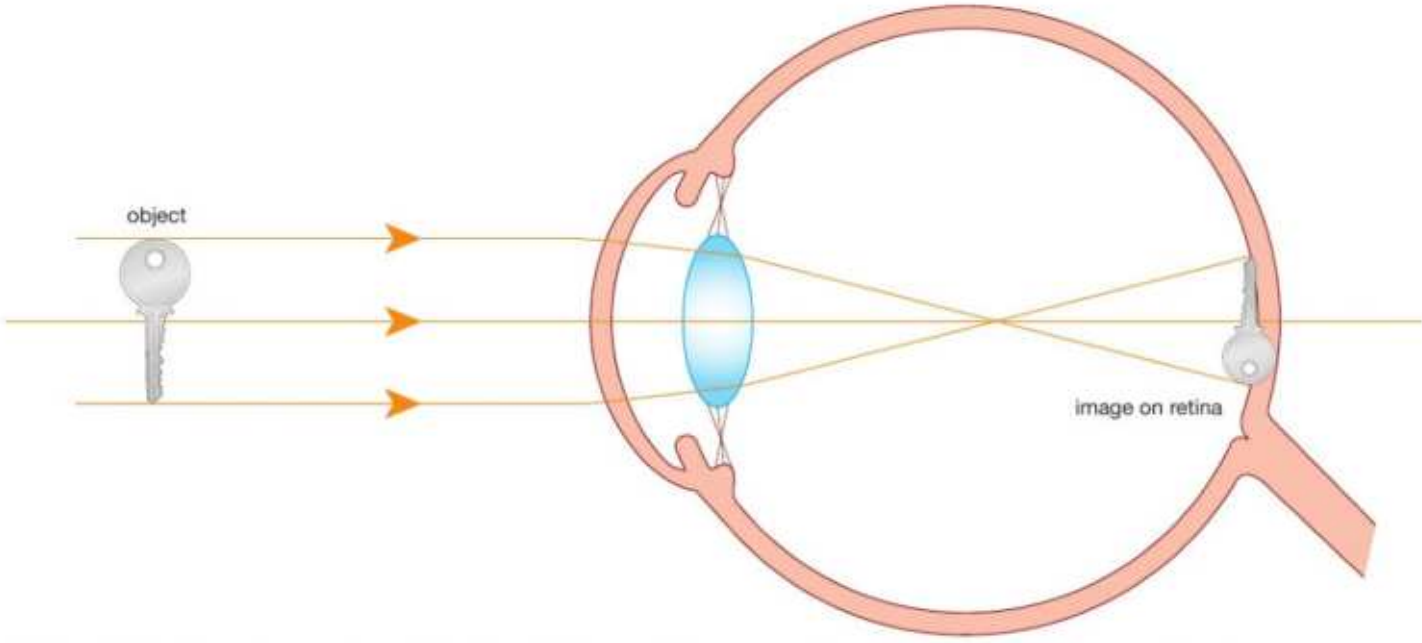
Underneath the sclera is a dark layer called the **choroid**. It is dark because it contains many pigment cells, as well as blood vessels. The pigment stops light being reflected around inside the eye.

The innermost layer of the back of the eye is the **retina**. This is the light-sensitive layer, the place where light energy is converted into the electrical energy of nerve impulses. The retina contains receptor cells called **rods** and **cones**. These cells react to light, producing impulses in sensory neurones. The sensory neurones then pass the impulses to the brain through the **optic nerve**. Rod cells work well in dim light, but they cannot distinguish between different colours, so the brain 'sees' an image produced by the rods in black and white. This is why we can't see colours very well in dim light: only our rods are working properly. The cones, on the other hand, will only work in bright light, and there are three types which respond to different wavelengths or colours of light – red, green and blue. We can see all the colours of visible light as a result of these three types of cones being stimulated to different degrees. For example, if red, green and blue are stimulated equally, we see white. Both rods and cones are found throughout the retina, but cones are particularly concentrated at the centre of the retina, in an area called the **fovea**. Cones give a sharper image than rods, which is why we can only see objects clearly if we are looking directly at them, so that the image falls on the fovea.

FORMING AN IMAGE

To form an image on the retina, light needs to be bent or *refracted*. Refraction takes place when light passes from one medium to another of a different density. In the eye, this happens first at the air/cornea boundary, and again at the lens (Figure 6.5). In fact the cornea acts as the first lens of the eye.

As a result of refraction at the cornea and lens, the image on the retina is inverted (upside down). The brain interprets the image the right way up.

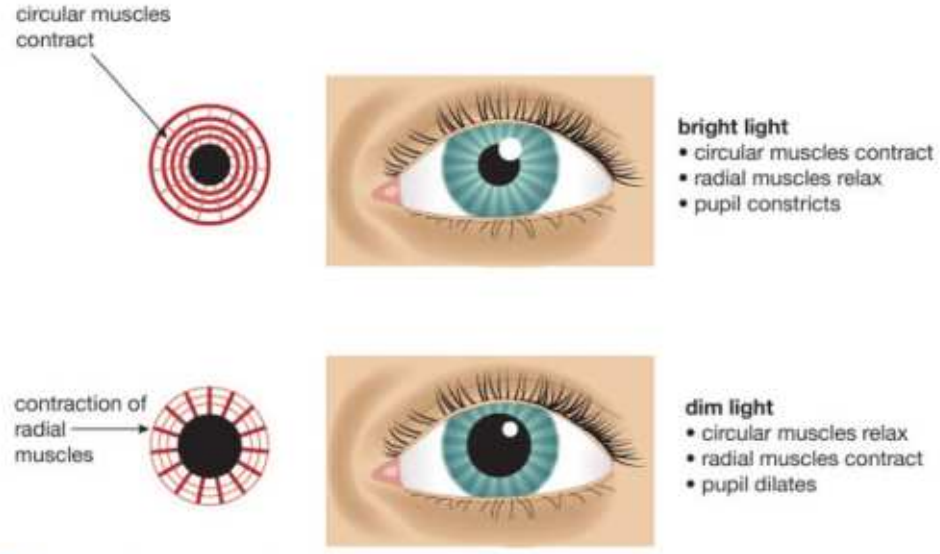


▲ Figure 6.5 How the eye forms an image. Refraction of light occurs at the cornea and lens, producing an inverted image on the retina.

THE IRIS REFLEX

The role of the iris is to control the amount of light entering the eye, by changing the size of the pupil. The iris contains two types of muscles. Circular muscles form a ring shape in the iris, and radial muscles lie like the spokes of a wheel. In bright light, the pupil is constricted (made smaller).

This happens because the circular muscles contract and the radial muscles relax. In dim light, the opposite happens. The radial muscles contract and the circular muscles relax, dilating (widening) the pupil (Figure 6.6).



▲ Figure 6.6 The amount of light entering the eye is controlled by the iris, which alters the diameter of the pupil.

KEY POINT

In the iris reflex, the route from stimulus to response is this:

stimulus (light intensity)
↓
retina (receptor)
↓
sensory neurones in optic nerve
↓
unconscious part of brain
↓
motor neurones in nerve to iris
↓
iris muscles (effector)
↓
response (change in size of pupil)

Whenever our eyes look from a dim light to a bright one, the iris rapidly and automatically adjusts the pupil size. This is an example of a **reflex action**. You will find out more about reflexes later in this chapter. The purpose of the iris reflex is to allow the right intensity (brightness) of light to fall on the retina. Light that is too bright could damage the rods and cones, and light that is too dim would not form an image. The intensity of light hitting the retina is the stimulus for this reflex. Impulses pass to the brain through the optic nerve, and straight back to the iris muscles, adjusting the diameter of the pupil. It all happens without the need for conscious thought – in fact we are not even aware of it happening.

THE BLIND SPOT

There is one area of the retina where an image cannot be formed; this is where the optic nerve leaves the eye. At this position there are no rods or cones, so it is called the **blind spot**. The retina of each eye has a blind spot, but they are not a problem, because the brain puts the images from each eye together, cancelling out the blind spots of both eyes. As well as this, the optic nerve leaves the eye towards the edge of the retina, where vision is not very sharp anyway. To 'see' your own blind spot you can do a simple experiment. Cover or close your right eye. Hold this page about 30 cm from your eyes and look at the black dot below. Now, without moving the book or turning your head, read the numbers from left to right by moving your left eye slowly towards the right.

• 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

You should find that when the image of the dot falls on the blind spot it disappears. If you try doing this with both eyes open, the image of the dot will not disappear.

DID YOU KNOW?

A way to prove to yourself that the eyes form two overlapping images is to try the 'sausage test'. Focus your eyes on a distant object. Place your two index fingers tip to tip, and bring them up in front of your eyes, about 30 cm from your face, while still focusing at a distance. You should see a finger 'sausage' between the two fingers. Now try this with one eye closed. What is the difference?

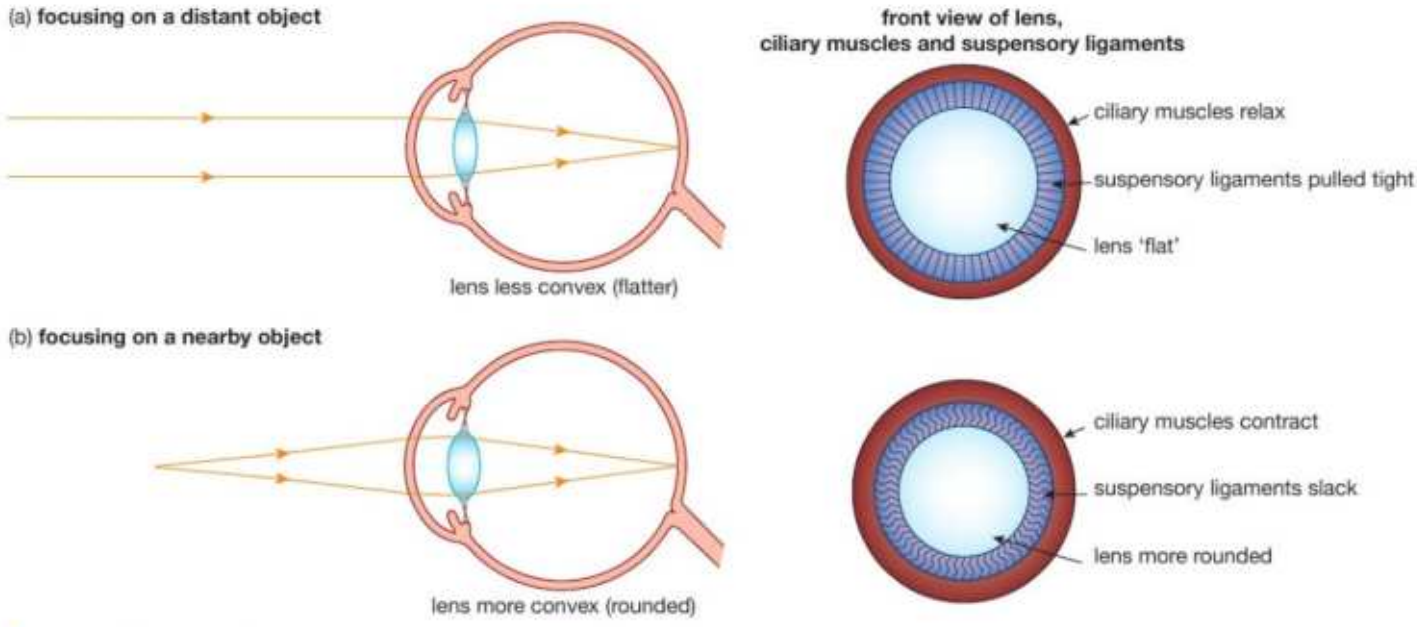
ACCOMMODATION

The changes that take place in the eye which allow us to see objects at different distances are called **accommodation**.

You have probably seen the results of a camera or projector not being in focus – a blurred picture. In a camera, we can focus light from objects that are different distances away by moving the lens backward or forward, until the picture is sharp. In the eye, a different method is used. Rather than altering its position, the shape of the lens can be changed. A lens that is fatter in the middle (more convex) will refract light rays more than a thinner (less convex) lens. The lens in the eye can change shape because it is made of cells containing an elastic crystalline protein.

Figure 6.4 shows that the lens is held in place by a series of fibres called the **suspensory ligaments**. These are attached like the spokes of a wheel to a ring of muscle, called the **ciliary muscle**. The inside of the eye is filled with

a transparent watery fluid which pushes outwards on the eye. In other words, there is a slight positive pressure within the eye. The changes to the eye that take place during accommodation are shown in Figure 6.7.

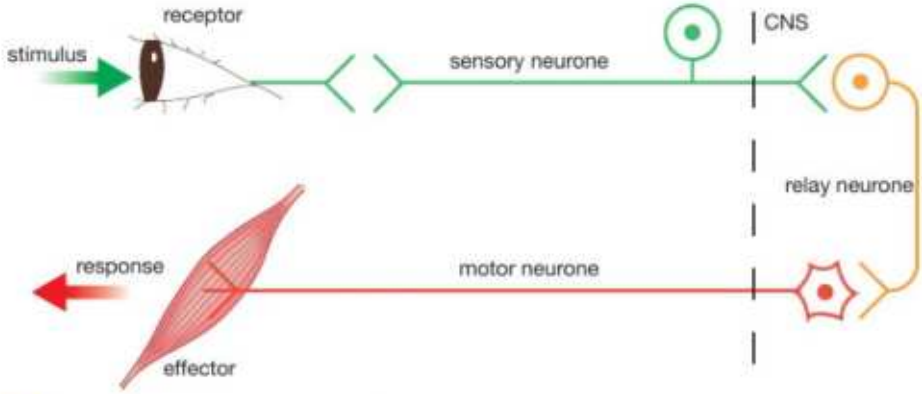


▲ Figure 6.7 Accommodation: how the eye focuses on objects at different distances

When the eye is focused on a distant object, the rays of light from the object are almost parallel when they reach the cornea (Figure 6.7(a)). The cornea refracts the rays, but the lens does not need to refract them much more to focus the light on the retina, so it does not need to be very convex. The ciliary muscles relax and the pressure in the eye pushes outwards on the lens, flattening it and stretching the suspensory ligaments. This is the condition when the eye is at rest – our eyes are focused for long distances.

When we focus on a nearby object, for example when reading a book, the light rays from the object are spreading out (diverging) when they enter the eye (Figure 6.7(b)). In this situation, the lens has to be more convex in order to refract the rays enough to focus them on the retina. The ciliary muscles now contract, the suspensory ligaments become slack and the elastic lens bulges outwards into a more convex shape.

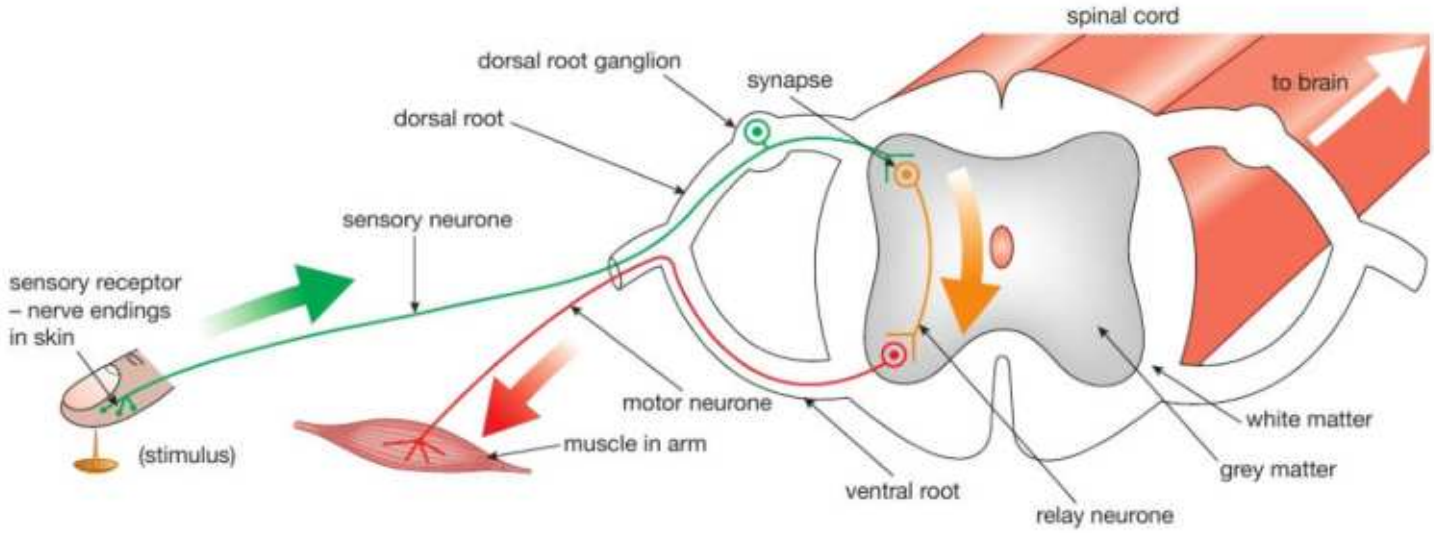
REFLEX ACTIONS



▲ Figure 6.8 Simplified diagram of a reflex arc

You saw on page 82 that the dilation and constriction of the pupil by the iris is an example of a reflex action. You now need to understand a little more about the nerves involved in a reflex. The nerve pathway of a reflex is called the **reflex arc**. The 'arc' part means that the pathway goes into the CNS and then straight back out again, in a sort of curve or arc (Figure 6.8).

The iris–pupil reflex protects the eye against damage by bright light. Other reflexes are protective too, preventing serious harm to the body. Take, for example, the reflex response to a painful stimulus. This happens when part of your body, such as your hand, touches a sharp or hot object. The reflex results in your hand being quickly withdrawn. Figure 6.9 shows the nerve pathway of this reflex in more detail.



▲ Figure 6.9 A reflex arc in more detail

KEY POINT

A reflex action is a *rapid*, *automatic* (or *involuntary*) response to a stimulus. The action often (but not always) protects the body. 'Involuntary' means that it is not started by impulses from the brain.

The stimulus is detected by temperature or pain receptors in the skin. These generate impulses in sensory neurones. The impulses enter the CNS through a part of the spinal nerve called the **dorsal root**. In the spinal cord the sensory neurones connect by synapses with short **relay neurones**, which in turn connect with motor neurones. The motor neurones emerge from the spinal cord through the **ventral root**, and send impulses back out to the muscles of the arm. These muscles then contract, pulling the arm (and thus finger) away from the harmful stimulus.

DID YOU KNOW?

'Dorsal' and 'ventral' are words describing the back and front of the body. The dorsal roots of spinal nerves emerge from the spinal cord towards the back of the person, while the ventral roots emerge towards the front. Notice that the cell bodies of the sensory neurones are all located in a swelling in the dorsal root, called the **dorsal root ganglion**.

The middle part of the spinal cord consists mainly of nerve cell bodies, which gives it a grey colour. This is why it is known as **grey matter**. The outer part of the spinal cord is called **white matter**, and has a whiter appearance because it contains many axons with their fatty myelin sheaths. (In the brain this is reversed – the grey matter is on the outside and the white matter in the middle of the brain.)

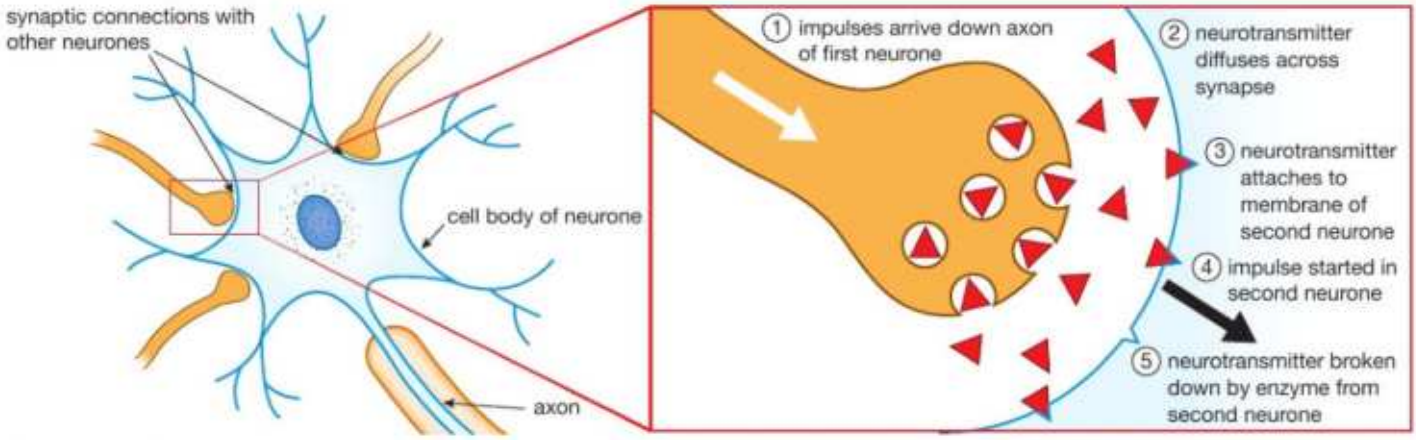
Impulses travel through the reflex arc in a fraction of a second, so that the reflex action is very fast, and doesn't need to be started by impulses from the brain. However, this doesn't mean that the brain is unaware of what is going on. This is because in the spinal cord, the reflex arc neurones also form connections called synapses (see below) with nerve cells leading to and from the brain. The brain therefore receives information about the stimulus. This is how we feel the pain.

Movements are sometimes a result of reflex actions, but we can also contract our muscles as a voluntary action, using nerve cell pathways from the brain linked to the same motor neurones. A voluntary action is under *conscious control*.

SYNAPSES

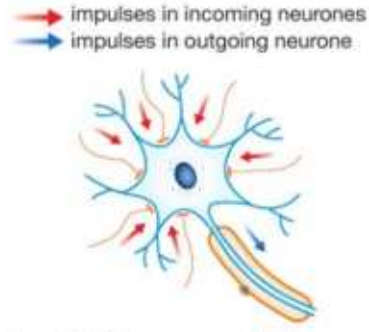
Synapses are critical to the working of the nervous system. The CNS is made of many billions of nerve cells, and these have links with many others, through synapses. In the brain, each neurone may form synapses with thousands of other neurones. It is estimated that there are between 100 and 1000 million *million* synapses in the CNS. Since impulses can take different routes through these, there is an almost infinite number of possible pathways through the system.

A synapse is actually a *gap* between two nerve cells. The gap is not crossed by the electrical impulses passing through the neurones, but by chemicals. Impulses arriving at a synapse cause the ends of the fine branches of the axon to secrete a chemical, called a **neurotransmitter**. This chemical diffuses across the gap and attaches to the membrane of the second neurone. It then starts off impulses in the second cell (Figure 6.10). After the neurotransmitter has 'passed on the message', it is broken down by an enzyme.



▲ Figure 6.10 The sequence of events happening at a synapse

Remember that many nerve cells, particularly those in the brain, have thousands of synapses with other neurones. The output of one cell may depend on the inputs from many cells adding together. In this way, synapses are important for integrating information in the CNS (Figure 6.11).



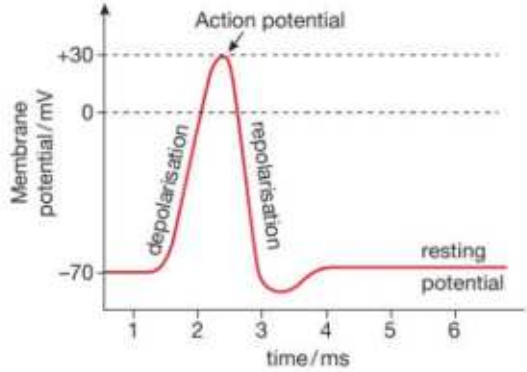
▲ Figure 6.11 Synapses allow the output of one nerve cell to be a result of integration of information from many other cells.

Because synapses are crossed by chemicals, it is easy for other chemicals to interfere with the working of the synapse. They may imitate the neurotransmitter, or block its action. This is the way that many drugs work.

LOOKING AHEAD – WHAT IS A NERVE IMPULSE?

A nerve impulse is an electrical signal that travels along the axon of a nerve cell. When the cell is not transmitting an impulse, there is small potential difference (voltage) across the nerve cell membrane. The potential inside the axon is about –70 mV lower than outside. This 'resting potential' is caused by differences in concentrations of various ions inside and outside the cell.

When the cell is stimulated, sodium ions (Na^+) rush into the axon through the membrane. The inflow of positively charged ions causes the potential to become positive – we say that it is *depolarised*. This sudden switch in voltage is called an 'action potential'. It only lasts for a few milliseconds (Figure 6.12). After a brief 'overshoot' below –70 mV it returns to normal (*repolarised*), as other positive ions (potassium, K^+) pass out through the membrane.



▲ Figure 6.12 Nerve cell action potential.

A nerve impulse is a *propagated* action potential. The action potential stimulates the next part of the cell membrane, so that the depolarisation spreads along the axon. After the action potential has passed, ion exchange pumps in the membrane sort out the imbalance of Na^+ and K^+ ions. The pumps use ATP for active transport – this is one reason why nerve cells need a lot of metabolic energy from respiration.

Nerve cells are called 'excitable cells' because they can change their membrane potential in this way. Other excitable cells include muscle and receptor cells. If you continue to study biology beyond International GCSE you will probably learn more about this interesting topic.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

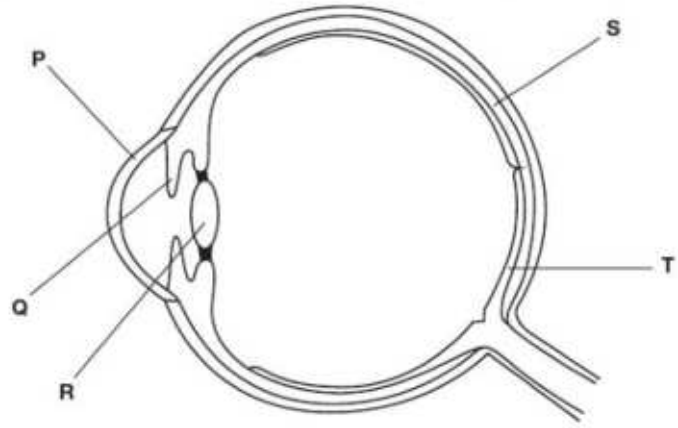
More questions on coordination can be found at the end of Unit 2 on page 116.

1 Which row in the table correctly describes the three types of neurone?

	Sensory neurone	Relay neurone	Motor neurone
A	connects neurones within the CNS	connects impulses to the effector from the CNS	connects impulses from the receptor to the CNS
B	connects impulses from the effector to the CNS	connects neurones within the CNS	connects impulses from the CNS to the receptor
C	connects neurones within the CNS	connects impulses from the receptor to the CNS	connects impulses to the effector from the CNS
D	connects impulses from the receptor to the CNS	connects neurones within the CNS	connects impulses to the effector from the CNS

SKILLS CRITICAL THINKING

2 The diagram below shows a section through the eye.



Which row in the table shows the cornea and the choroid?

	Cornea	Choroid
A	R	T
B	P	S
C	R	P
D	Q	T

3 A boy sits in the shade under a tree, reading a book. He looks up into the sunny sky at an aeroplane. Which of the following changes will take place in his eyes?

A The pupils dilate and the lens becomes less convex

B The pupils dilate and the lens becomes more convex

C The pupils constrict and the lens becomes less convex

D The pupils constrict and the lens becomes more convex

4 Below are two statements about how nerve cells work.

1. Neurotransmitters carry a nerve impulse along a neurone
2. An electrical charge carries a nerve impulse across a synapse

Which of these statements is/are true?

A 1 **B** 2

C 1 and 2 **D** neither

5 A cataract is an eye problem suffered by some people, especially the elderly. The lens of the eye becomes opaque (cloudy) which blocks the passage of light. It can lead to blindness. Cataracts can be treated by a simple eye operation, where a surgeon removes the lens and replaces it with an artificial lens. After the operation, the patient is able to see again, but the eye is unable to carry out accommodation, and the patient will probably need to wear glasses for close-up work, such as reading.

a What is meant by 'accommodation'?

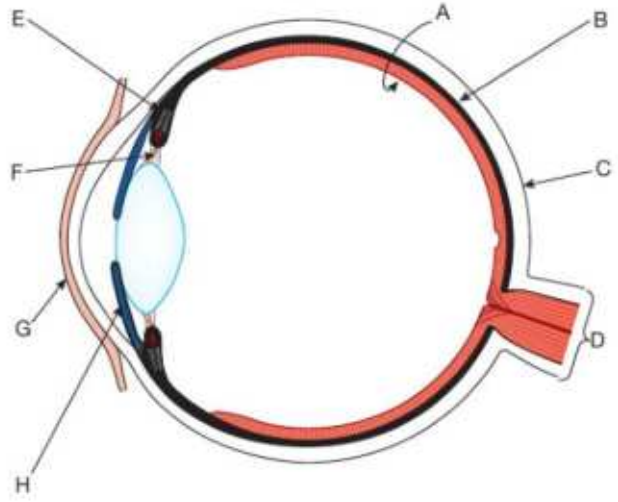
SKILLS REASONING

b Why is accommodation not possible after a cataract operation?

c Explain how a normal eye accommodates to focus on a nearby object.

SKILLS ANALYSIS

6 The diagram shows a section through a human eye.



a The table below lists the functions of some of parts A to H. Copy the table and write the letters of the correct parts in the boxes.

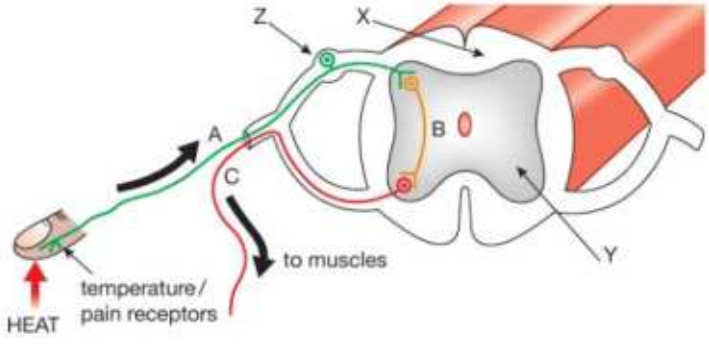
Function	Letter
refracts light rays	
converts light into nerve impulses	
contains pigment to stop internal reflection	
contracts to change the shape of the lens	
takes nerve impulses to the brain	

b i Which label shows the iris?

ii Explain how the iris controls the amount of light entering the eye.

iii Why is this important?

7 The diagram shows some parts of the nervous system involved in a simple reflex action that happens when a finger touches a hot object.



a What type of neurone is:

i neurone A

ii neurone B

iii neurone C?

b Describe the function of each of these types of neurone.

c Which parts of the nervous system are shown by the labels X, Y and Z?

SKILLS CRITICAL THINKING

d In what form is information passed along neurones?

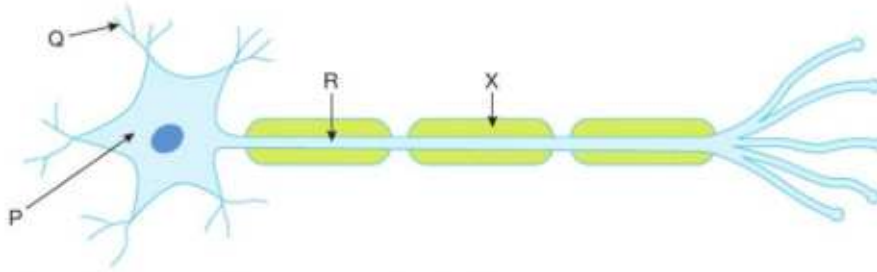
e Explain how information passes from one neurone to another.

SKILLS REASONING

f Some drugs act at a synapse to prevent a person feeling pain. From your knowledge of synapses, suggest how they might work.

SKILLS PROBLEM SOLVING

8 The diagram shows a motor neurone.



Name the parts of the neurone labelled P, Q and R.

a This motor neurone is 1.2 metres in length. It takes 0.016 seconds for an impulse to pass along the neurone. Calculate the speed of conduction of the impulse.

SKILLS CRITICAL THINKING

b Neurones need energy from ATP to conduct impulses. Name the organelle in the cell that provides most of this ATP.

c Structure R is surrounded by a sheath, labelled X in the diagram. What is the function of this sheath?

SKILLS REASONING

d Some diseases can cause damage to this sheath. Suggest what would happen to a person's nervous responses if this sheath were to be damaged.

SKILLS CRITICAL THINKING

9 a List five examples of stimuli that affect the body and state the response produced by each stimulus.

b For one of your five examples, explain:

i the nature and role of the receptor

ii the nature and role of the effector organ.

c For the same example, describe the chain of events from stimulus to response.

7 CHEMICAL COORDINATION

The nervous system (Chapter 6) is a coordination system forming a link between stimulus and response. The body has a second coordination system, which does not involve nerves. This is the endocrine system. It consists of organs called endocrine glands, which make chemical messenger substances called hormones. Hormones are carried in the bloodstream.

LEARNING OBJECTIVES

- Describe how responses can be controlled by hormonal communication
- Understand the differences between nervous and hormonal control
- Understand the sources, roles and effects of the following hormones:
  - adrenaline
  - insulin
  - testosterone*
  - progesterone*
  - oestrogen*

*These hormones will be dealt with in more detail in later chapters.

GLANDS AND HORMONES

A gland is an organ that releases or *secretes* a substance. This means that cells in the gland make a chemical which leaves the cells through the cell membrane. The chemical then travels somewhere else in the body, where it carries out its function. There are two types of glands – exocrine and endocrine glands. **Exocrine glands** secrete their products through a tube called a duct. For example, salivary glands in your mouth secrete saliva down salivary ducts, and tear glands secrete tears through ducts that lead to the surface of the eye. **Endocrine glands** have no duct, and so are called ductless glands. Instead, their products, the **hormones**, are secreted into the blood vessels that pass through the gland (Figure 7.1).



▲ Figure 7.1 Exocrine glands secrete their products though a duct, while endocrine glands secrete hormones into the blood.

This chapter looks at some of the main endocrine glands and the functions of the hormones they produce. Because hormones are carried in the blood, they can travel to all areas of the body. They usually only affect certain tissues or organs, called 'target organs', which can be a long distance from the gland

KEY POINT

The receptors for some hormones are located in the cell membrane of the target cell. Other hormones have receptors in the cytoplasm, and some in the nucleus. Without specific receptors, a cell will not respond to a hormone at all.

that made the hormone. Hormones only affect particular tissues or organs if the cells of that tissue or organ have special chemical receptors for the particular hormone. For example, the hormone **insulin** affects the cells of the liver, which have insulin receptors.

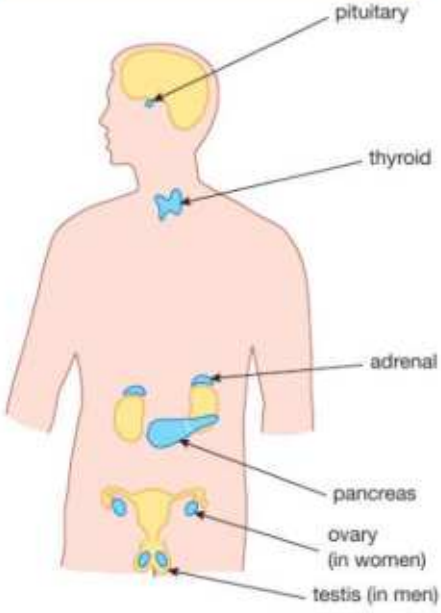
THE DIFFERENCES BETWEEN NERVOUS AND ENDOCRINE CONTROL

Although the nervous and endocrine systems both act to coordinate body functions, there are differences in the way that they do this. These are summarised in Table 7.1.

Table 7.1 The nervous and endocrine systems compared.

Nervous system	Endocrine system
works by nerve impulses transmitted through nerve cells (although chemicals are used at synapses)	works by hormones transmitted through the bloodstream
nerve impulses travel fast and usually have an 'instant' effect	hormones travel more slowly and generally take longer to act
response is usually short-lived	response is usually longer-lasting
impulses act on individual cells such as muscle fibres, so have a very localised effect	hormones can have widespread effects on different organs (although they only act on particular tissues or organs if the cells have the correct receptors)

THE ENDOCRINE GLANDS



▲ Figure 7.2 The main endocrine glands of the body.

The positions of the main endocrine glands are shown in Figure 7.2. A summary of some of the hormones that they make and their functions is given in Table 7.2.

The **pituitary gland** (often just called 'the pituitary') is found at the base of the brain. It produces a number of hormones controlling various processes in the body. It also controls the release of certain hormones from other endocrine glands.

Table 7.2: Some of the main endocrine glands, the hormones they produce and their functions.

Gland	Hormone	Some functions of the hormones
thyroid	thyroxine	controls the body's metabolic rate (how fast chemical reactions take place in cells)
pancreas	insulin glucagon	lowers blood glucose raises blood glucose
adrenals	adrenaline	prepares the body for physical activity
testes	testosterone	controls the development of male secondary sexual characteristics
ovaries	oestrogen progesterone	controls the development of female secondary sexual characteristics regulates the menstrual cycle

The **pancreas** is both an endocrine *and* an exocrine gland. It secretes two hormones involved in the regulation of blood glucose, and is also a gland of the digestive system, secreting enzymes through the pancreatic duct into the small intestine (see Chapter 4). The sex organs of males (**testes**) and females (**ovaries**) are also endocrine organs. In addition to their role in producing sex cells, the testes and ovaries make hormones that are involved in controlling reproduction. This topic is covered more fully in Chapter 9. We will now look at the functions of two hormones in more detail.

ADRENALINE – THE 'FIGHT OR FLIGHT' HORMONE

DID YOU KNOW?

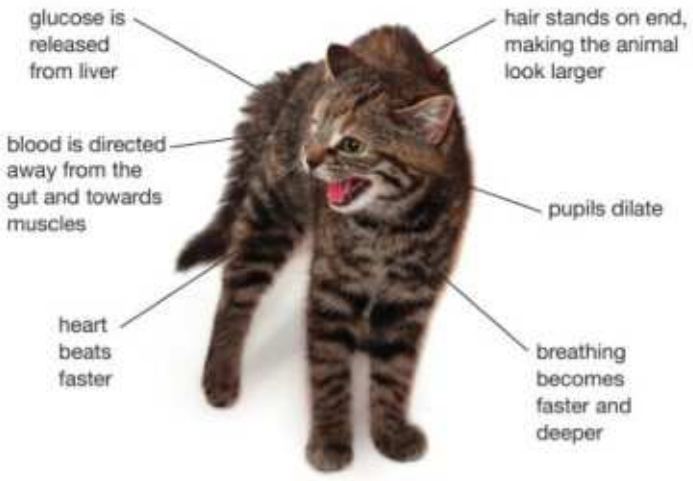
'Adrenal' means 'next to the kidneys', which describes where the adrenal glands are located – on top of these organs (see Figure 7.2).

When you are frightened, excited or angry, your **adrenal glands** secrete the hormone adrenaline.

Adrenaline acts at a number of target organs and tissues, preparing the body for action. In animals other than humans this action usually means dealing with an attack by an enemy, where the animal can stay and fight or run away – hence 'fight or flight'. This is not often a problem with humans, but there are plenty of other times when adrenaline is released (Figure 7.3).



▲ Figure 7.3 Many human activities cause adrenaline to be produced, not just a 'fight or flight' situation!



▲ Figure 7.4 Adrenaline affects the body of an animal in many ways.

If an animal's body is going to be prepared for action, the muscles need a good supply of oxygen and glucose for respiration. Adrenaline produces several changes in the body that make this happen (Figure 7.4) as well as other changes to prepare for fight or flight.

- The breathing rate increases and breaths become deeper, taking more oxygen into the body.
- The heart beats faster, sending more blood to the muscles, so that they receive more glucose and oxygen for respiration.
- Blood is diverted away from the intestine and into the muscles.
- In the liver, stored carbohydrate (glycogen) is changed into glucose and released into the blood. The muscle cells absorb more glucose and use it for respiration.
- The pupils dilate, increasing visual sensitivity to movement.
- Body hair stands upright, making the animal look larger to an enemy.
- Mental awareness is increased, so reactions are faster.

In humans, adrenaline is not just released in a 'fight or flight' situation, but in many other stressful activities too, such as preparing for a race, going for a job interview or taking an exam.

INSULIN – CONTROL OF BLOOD GLUCOSE

You saw earlier that adrenaline can raise blood glucose from stores in the liver. The liver cells contain carbohydrate in the form of **glycogen**. Glycogen is made from long chains of glucose sub-units joined together, forming a large insoluble molecule (see Chapter 4). Being insoluble makes glycogen a good storage product. When the body is short of glucose, the glycogen can be broken down into glucose, which then passes into the bloodstream.

Adrenaline raises blood glucose concentration in an emergency, but other hormones act all the time to control the level, keeping it fairly constant at a little less than 1 g of glucose in every dm^3 (cubic decimetre) of blood. The main hormone controlling glucose is insulin. Insulin is made by special cells in the pancreas. It stimulates the liver cells to take up glucose and convert it into glycogen, lowering the level of glucose in the blood.

DID YOU KNOW?

The pancreas also makes a hormone called **glucagon**, which has the opposite effect to insulin – it raises blood glucose.

The concentration of glucose in your blood will start to rise after you have had a meal. Sugars from digested carbohydrate pass into the blood and are carried to the liver in the hepatic portal vein (Chapter 5). In the liver the glucose is converted to glycogen, so the blood leaving the liver in the hepatic vein has a lower concentration of glucose than when it enters the liver.

DIABETES

Some people have a disease where their pancreas cannot make enough insulin to keep their blood glucose level constant – it rises to very high concentrations. The disease is called **diabetes**. One symptom of diabetes can be detected by a chemical test on urine. Normally, people have no glucose at all in their urine. Someone suffering from diabetes may have such a high concentration of glucose in the blood that it is excreted in their urine. This can be shown up by using coloured test strips (Figure 7.5).



▲ Figure 7.5 Coloured test strips are used to detect glucose in urine.

KEY POINT

We should really refer to this disease by its full name, which is 'type 1' diabetes. There is also a 'type 2' diabetes, where the pancreas produces insulin but the body shows *insulin resistance*, where insulin has less effect than it should do. At first the pancreas makes extra insulin, but eventually it can't continue to make enough to maintain blood glucose at a normal level. Type 2 diabetes is common in people who are overweight and eat a poor diet that is high in sugar and other carbohydrates. It can be prevented and controlled by eating a good diet and doing regular exercise. Type 2 diabetes also tends to happen in middle-aged or older people, whereas type 1 can happen at any age, and is common in childhood.

Another symptom of diabetes is a constant thirst. This is because the high blood glucose concentration stimulates receptors in the **hypothalamus** of the brain. These 'thirst centres' are stimulated, so that by drinking, the person will dilute their blood.

Severe diabetes is very serious. If it is untreated, the sufferer loses weight and becomes weak and eventually falls into a coma and dies.

Carbohydrates in the diet, such as starch and sugars, are the source of glucose in the blood, so a person with diabetes can help to control their blood sugar if they limit the amount of carbohydrate that they eat. However a person

KEY POINT

Insulin is a protein, and if it were to be taken by mouth in tablet form, it would be broken down by protease enzymes in the gut. Instead it is injected into muscle tissue, where it is slowly absorbed into the bloodstream.

with diabetes (type 1) also needs to receive daily injections of insulin to keep the glucose in their blood at the right level.

People with diabetes can check their blood glucose using a special sensor. They prick their finger and place a drop of blood on a test strip. The strip is then put into the sensor, which gives them an accurate reading of how much glucose is in their blood (Figure 7.6). They can then tell when to inject insulin and how much to inject.

DID YOU KNOW?

Insulin for the treatment of diabetes has been available since 1921, and has kept millions of people alive. It was originally extracted from the pancreases of animals and much insulin is still obtained in this way. However, since the 1970s, human insulin has been produced commercially, from genetically modified (GM) bacteria. The bacteria have their DNA 'engineered' to contain the gene for human insulin (see Chapter 21).



▲ Figure 7.6 Sensor for measuring blood glucose

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

More questions on chemical coordination can be found at the end of Unit 2 on page 116.

1 Which of the following statement(s) is/are true?

1. Insulin converts glucose to glycogen
2. Insulin causes blood glucose levels to fall
3. Glucose is stored as glucagon in the liver
4. Glycogen can be broken down to release glucose into the blood

A 2 only

B 2 and 4

C 3 and 4

D 1 and 2

2 Which of the following will *not* happen when the hormone adrenaline is released?

A an increase in heart rate

B an increase in blood flow to the gut

C dilation of the pupils

D an increase in breathing rate

SKILLS CRITICAL THINKING

3 Which of the following is a symptom of type 1 diabetes?

A high insulin level in the blood

B low glucose level in the blood

C glucose present in the urine

D insulin present in the urine

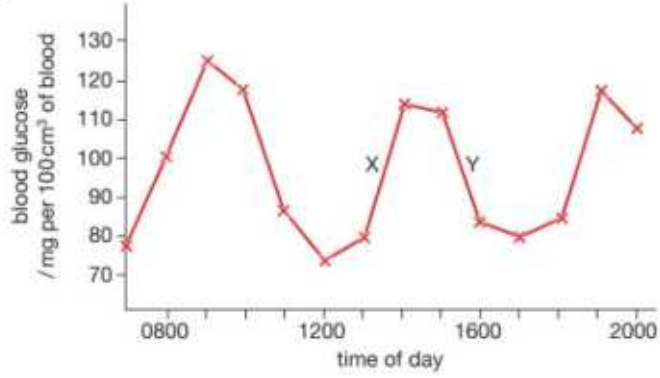
4 a *Hormones* are *secreted* by *endocrine glands*. Explain the meaning of the four words in italics

SKILLS ANALYSIS

b Identify the hormones A to D in the table.

Hormone	One function of this hormone
A	stimulates the liver to convert glucose to glycogen
B	controls the 'fight or flight' responses
C	controls the breaking of the voice at puberty in boys
D	completes the development of the uterus lining during the menstrual cycle

5 The graph shows the changes in blood glucose in a healthy woman over a 12-hour period.



a Explain why there was a rise in blood glucose at X.

b How does the body bring about a decrease in blood glucose at Y? Your answer should include the words insulin, liver and pancreas.

c Diabetes is a disease where the body cannot control the concentration of glucose in the blood.

SKILLS CRITICAL THINKING

i Why is this dangerous?

ii Describe two ways a person with diabetes can monitor their blood glucose level.

iii Explain two ways that a person with diabetes can help to control their blood glucose level.

8 HOMEOSTASIS AND EXCRETION

The kidneys have major roles to play in both homeostasis and excretion. This chapter is mainly concerned with the structure and function of the kidneys. It also deals with another important aspect of homeostasis – maintaining a steady body temperature.

LEARNING OBJECTIVES

- Understand that homeostasis is the maintenance of a constant internal environment
- Understand that control of body water content and body temperature are examples of homeostasis
- Know the excretory products of the lungs, kidneys and skin
- Understand the origin of carbon dioxide and oxygen as waste products of metabolism and their loss from the stomata of a leaf
- Describe the role of the skin in temperature regulation, with reference to sweating, vasoconstriction and vasodilation

Inside our bodies, conditions are kept relatively constant. This is called **homeostasis**. The kidneys are organs which have a major role to play in both homeostasis and in the removal of waste products, or **excretion**. They filter the blood, removing substances and controlling the concentration of water and solutes (dissolved substances) in the blood and other body fluids.

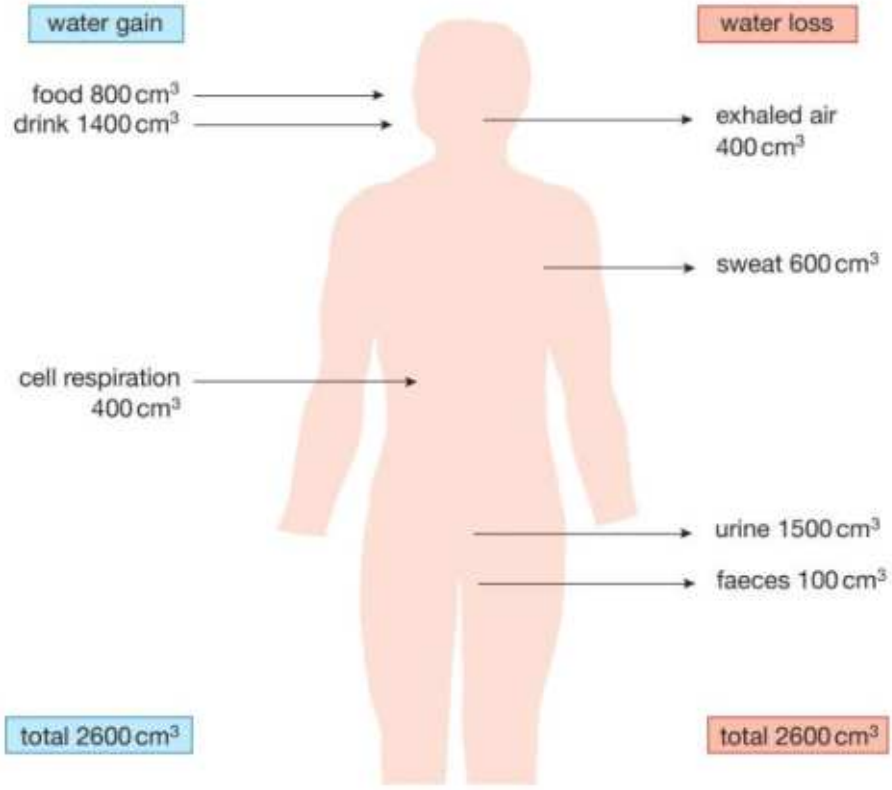
HOMEOSTASIS

KEY POINT

The meaning of 'homeostasis' is 'keeping the conditions in the internal environment of the body relatively constant'. One aspect of homeostasis is the maintenance of the water and salt content of the internal environment. This is called **osmoregulation**.

If you were to drink a litre of water and wait for half an hour, your body would soon respond to this change by producing about the same volume of urine. In other words, it would automatically balance your water input and water loss. Drinking is the main way that our bodies gain water, but there are other sources (Figure 8.1). Some water is present in the food that we eat, and a small amount is formed by cell respiration. The body also loses water, mostly in urine, but also smaller volumes in sweat, faeces and exhaled air. Every day, we gain and lose about the same volume of water, so that the total content of our bodies stays more or less the same. This is an example of homeostasis. The word 'homeostasis' means 'steady state', and refers to keeping conditions inside the body relatively constant.

The inside of the body is known as the **internal environment**. You have probably heard of the 'environment', which means the 'surroundings' of an organism. The *internal* environment is the surroundings of the cells inside the body. It particularly means the blood, together with another liquid called **tissue fluid**.



▲ Figure 8.1 The daily water balance of an adult

Tissue fluid is a watery solution of salts, glucose and other solutes. It surrounds all the cells of the body, forming a pathway for the transfer of nutrients between the blood and the cells. Tissue fluid is formed by leakage from blood capillaries. It is similar in composition to blood plasma, but lacks the plasma proteins.

It is not just water and salts that are kept constant in the body. Many other components of the internal environment are maintained. For example, the level of carbon dioxide in the blood is regulated, along with the blood pH, the concentration of dissolved glucose (see Chapter 7) and the body temperature.

Homeostasis is important because cells will only function properly if they are bathed in a tissue fluid which provides them with their optimum conditions. For instance, if the tissue fluid contains too many solutes, the cells will lose water by osmosis, and become dehydrated. If the tissue fluid is too dilute, the cells will swell up with water. Both conditions will prevent them working efficiently and might cause permanent damage. If the pH of the tissue fluid is not correct, it will affect the activity of the cell's enzymes, as will a body temperature much different from 37 °C. It is also important that excretory products are removed. Substances such as urea must be prevented from building up in the blood and tissue fluid, where they would be toxic to cells.

DID YOU KNOW?

'Salts' in urine or in the blood are present as ions. For example, the sodium chloride in Table 8.1 will be in solution as sodium ions (Na^+) and chloride ions (Cl^-). Urine contains many other ions, such as potassium (K^+), phosphate (HPO_4^{2-}) and ammonium (NH_4^+), and removes excess ions from the blood.

URINE

An adult human produces about 1.5 dm^3 of urine every day, although this volume depends very much on the amount of water drunk and the volume lost in other forms, such as sweat. Every litre of urine contains about 40 g of waste products and salts (Table 8.1).

KEY POINT

If you are studying for the Double Award, you only need to be aware that urea is an excretory product of the kidneys.

Table 8.1 Some of the main solutes in urine.

Substance	Amount / g per dm^3
urea	23.3
ammonia	0.4
other nitrogenous waste	1.6
sodium chloride (salt)	10.0
potassium	1.3
phosphate	2.3

Notice the words *nitrogenous waste*. Urea and ammonia are two examples of nitrogenous waste. It means that they contain the element nitrogen. All animals have to excrete a nitrogenous waste product.

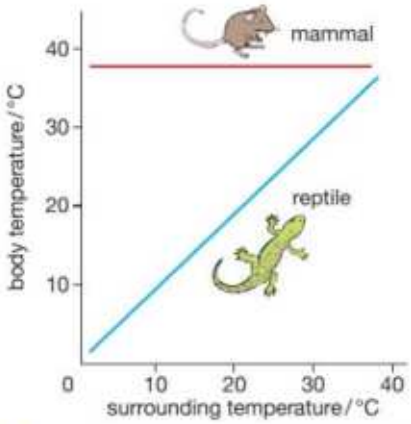
KEY POINT

Excretion is the process by which waste products of metabolism are removed from the body. In humans, the main nitrogenous excretory substance is **urea**. Another excretory product is carbon dioxide, produced by cell respiration and excreted by the lungs (Chapter 3). The human skin is also an excretory organ, since the sweat that it secretes contains small amounts of urea.

Plants also excrete waste products of metabolism. In light, their leaves produce oxygen from photosynthesis. In the dark they excrete carbon dioxide from respiration. Plants exchange these gases through pores in the leaf called stomata (see Chapter 11).

The reason behind this is quite complicated. Carbohydrates and fats only contain the elements carbon, hydrogen and oxygen. However, proteins also contain nitrogen. If the body has too much carbohydrate or fat, these substances can be stored, for example as glycogen in the liver, or as fat under the skin and around other organs. Excess proteins, or their building blocks (called amino acids) *cannot* be stored. The amino acids are first broken down in the liver. They are converted into carbohydrate (which is stored as glycogen) and the main nitrogen-containing waste product, urea. The urea passes into the blood, to be filtered out by the kidneys during the formation of urine. Notice that the urea is made by chemical reactions in the cells of the body (the body's metabolism). 'Excretion' means getting rid of waste of this kind. When the body gets rid of solid waste from the digestive system (faeces), this is not excretion, since it contains few products of *metabolism*, just the 'remains' of undigested food, along with bacteria and dead cells.

So the kidney is in fact carrying out two functions. It is a *homeostatic* organ, controlling the water and salt (ion) concentration in the body as well as an *excretory* organ, concentrating nitrogenous waste in a form that can be eliminated.



▲ Figure 8.2 The temperature of a homeotherm, such as a mammal, is kept constant at different external temperatures, whereas the lizard's body temperature changes.

CONTROL OF BODY TEMPERATURE

You may have heard mammals and birds described as 'warm blooded'. A better word for this is homeothermic. It means that they keep their body temperature constant, despite changes in the temperature of their surroundings. For example, the body temperature of humans is kept steady at about 37 °C, give or take a few tenths of a degree. This is another example of homeostasis. All other animals are 'cold blooded'. For example, if a lizard is kept in an aquarium at 20 °C, its body temperature will be 20 °C too. If the temperature of the aquarium is raised to 25 °C, the lizard's body temperature will rise to 25 °C as well. We can show this difference between **homeotherms** and other animals as a graph (Figure 8.2).

In the wild, lizards keep their temperature more constant than in Figure 8.2, by adapting their behaviour. For example, in the morning they may stay in the sun to warm their bodies, or at midday, if the sun is too hot, retreat to holes in the ground to cool down.

DID YOU KNOW?

Physiology is the branch of biology that deals with how the bodies of animals or plants work, for example how muscles contract, how nerves send impulses, or how xylem carries water through plants. In this chapter you have read about kidney physiology.

The real difference between homeotherms and all other animals is that homeotherms can keep their temperatures constant by using *physiological* changes for generating or losing heat. For this reason, mammals and birds are also called 'endotherms', meaning 'heat from inside'.

An endotherm uses heat from the chemical reactions in its cells to warm its body. It then controls its heat loss by regulating processes like sweating and blood flow through the skin. Endotherms use behavioural ways to control their temperature too. For example, penguins 'huddle' together in groups to keep warm, and humans put on extra clothes in winter.

What is the advantage of a human maintaining a body temperature of 37 °C? It means that all the chemical reactions taking place in the cells of the body can go on at a steady, predictable rate. The metabolism doesn't slow down in cold environments. If you watch goldfish in a garden pond, you will notice that in summer, when the pond water is warm, they are very active, swimming about quickly. In winter, when the temperature drops, the fish slow down and become very sluggish in their actions. This would happen to a mammal too, if its body temperature varied.

It is also important that the body does not become *too* hot. The cells' enzymes work best at 37 °C. At higher temperatures enzymes, like all proteins, are destroyed by **denaturing** (see Chapter 1). Endotherms have all evolved a body temperature of around 40 °C (Table 8.2) and enzymes that work best at this temperature.

Table 8.2 The body temperatures of a range of mammals and birds

Species	Average and normal range of body temperature / °C	Species	Average and normal range of body temperature / °C
brown bear	38.0 ± 1.0	shrew	35.7 ± 1.2
camel	37.5 ± 0.5	whale	35.7 ± 0.1
elephant	36.2 ± 0.5	duck	43.1 ± 0.3
fox	38.8 ± 1.3	ostrich	39.2 ± 0.7
human	36.9 ± 0.7	penguin	39.0 ± 0.2
mouse	39.3 ± 1.3	thrush	40.0 ± 1.7
polar bear	37.5 ± 0.4	wren	41.0 ± 1.0

MONITORING BODY TEMPERATURE

In humans and other mammals the core body temperature is monitored by a part of the brain called the **thermoregulatory centre**. This is located in the hypothalamus of the brain. It acts as the body's 'thermostat'.

If a person goes into a warm or cold environment, the first thing that happens is that temperature receptors in the skin send electrical impulses to the hypothalamus, which stimulates the brain to alter our behaviour. We start to feel hot or cold, and usually do something about it, such as finding shade, having a cold drink, or putting on more clothes.

If changes to our behaviour are not enough to keep our body temperature constant, the thermoregulatory centre in the hypothalamus detects a change in the temperature of the blood flowing through it. It then sends signals via nerves to other organs of the body, which regulate the temperature by physiological means.

DID YOU KNOW?

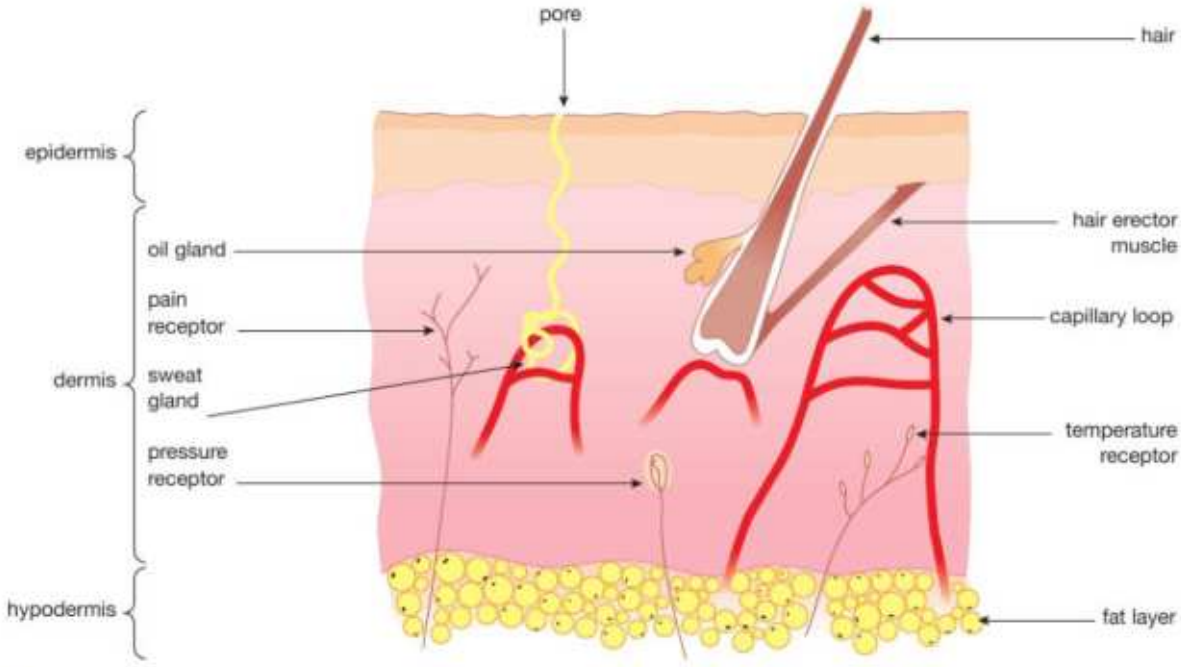
A thermostat is a switch that is turned on or off by a change in temperature. It is used in electrical appliances to keep their temperature steady. For example, a thermostat in an iron can be set to 'hot' or 'cool' to keep the temperature of the iron set for ironing different materials.

THE SKIN AND TEMPERATURE CONTROL

The human skin has a number of functions related to the fact that it forms the outer surface of the body. These include:

- forming a tough outer layer able to resist mechanical damage
- acting as a barrier to the entry of pathogens
- forming an impermeable surface, preventing loss of water
- acting as a sense organ for touch and temperature changes
- controlling the loss of heat through the body surface.

Figure 8.3 shows the structure of human skin. It is made up of three layers: the epidermis, dermis and hypodermis.



▲ Figure 8.3 A section through human skin

The outer **epidermis** consists of dead cells that stop water loss and protect the body against invasion by microorganisms such as bacteria. The **hypodermis** contains fatty tissue, which insulates the body against heat loss and is a store of energy. The middle layer, the **dermis**, contains many sensory receptors. It is also the location of sweat glands and many small blood vessels, as well as hair follicles. These last three structures are involved in temperature control.

Imagine that the hypothalamus detects a rise in the central (core) body temperature. Immediately it sends nerve impulses to the skin. These bring about changes to correct the rise in temperature.

First of all, the **sweat glands** produce greater amounts of sweat. This liquid is secreted onto the surface of the skin. When a liquid evaporates, it turns into a gas. This change needs energy, called the latent heat of vaporisation. When

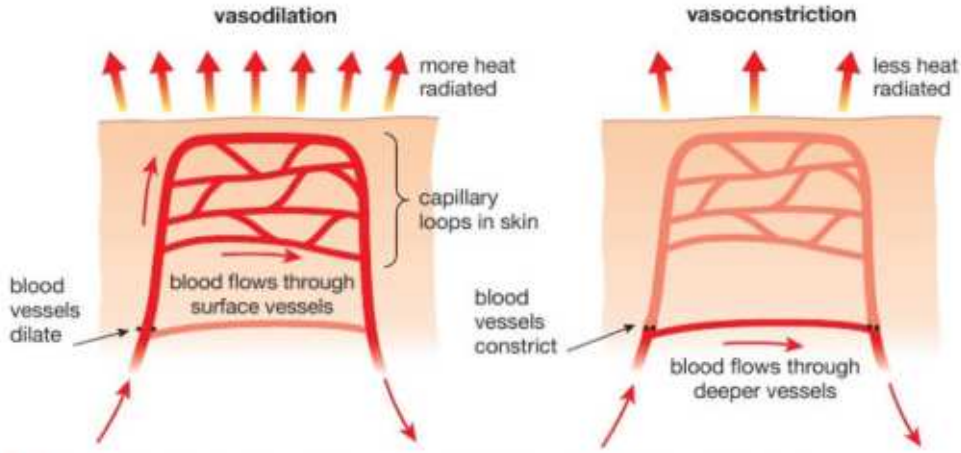
sweat evaporates, the energy is supplied by the body's heat, cooling the body down. It is not that the sweat is cool – it is secreted at body temperature. It only has a cooling action when it evaporates. In very humid atmospheres (e.g. a tropical rainforest) the sweat stays on the skin and doesn't evaporate. It then has very little cooling effect.

Secondly, hairs on the surface of the skin lie flat against the skin's surface. This happens because of the relaxation of tiny muscles called **hair erector muscles** attached to the base of each hair. In cold conditions, these contract and the hairs are pulled upright. The hairs trap a layer of air next to the skin, and since air is a poor conductor of heat, this acts as insulation. In warm conditions, the thinner layer of trapped air means that more heat will be lost. This is not very effective in humans, because the hairs over most of our body do not grow very large. It is very effective in hairy mammals like cats or dogs. The same principle is used by birds, which 'fluff out' their feathers in cold weather.

HINT

Students often describe vasodilation incorrectly. They talk about the blood vessels 'moving nearer the surface of the skin'. They don't *move* at all, it's just that more blood flows through the surface vessels.

Lastly, there are tiny blood vessels called capillary loops in the dermis. Blood flows through these loops, radiating heat to the outside, and cooling the body down. If the body is too hot, **arterioles** (small arteries) leading to the capillary loops dilate (widen). This increases the blood flow to the skin's surface (Figure 8.4) and is called **vasodilation**.



▲ Figure 8.4 Blood flow through the surface of the skin is controlled by vasodilation or vasoconstriction.

In cold conditions, the opposite happens. The arterioles leading to the surface capillary loops constrict (become narrower) and blood flow to the surface of the skin is reduced, so that less heat is lost. This is called **vasoconstriction.** Vasoconstriction and vasodilation are brought about by tiny rings of muscles in the walls of the arterioles, called sphincter muscles, like the sphincters you read about earlier in this chapter, at the outlet of the bladder.

There are other ways that the body can control heat loss and heat gain. In cold conditions, the body's metabolism speeds up, generating more heat. The liver, a large organ, can produce a lot of metabolic heat in this way. The hormone adrenaline stimulates the increase in metabolism (see Chapter 7). **Shivering** also takes place, where the muscles contract and relax rapidly. This also generates a large amount of heat.

Sweating, vasodilation and vasoconstriction, hair erection, shivering and changes to the metabolism, along with behavioural actions, work together to keep the body temperature to within a few tenths of a degree of the 'normal' 37 °C. If the difference is any bigger than this it shows that something is wrong. For instance, a temperature of 39 °C might be due to an illness.

CHAPTER QUESTIONS

More questions on homeostasis and excretion can be found at the end of Unit 2 on page 116.

SKILLS CRITICAL THINKING

1 Which of the following is *not* an example of excretion?

A loss of carbon dioxide by a plant in the dark
B removal of carbon dioxide from the lungs
C removal of urea in urine
D elimination of faeces from the alimentary canal

2 If the human body temperature starts to rise, which of the following happens?

A vasoconstriction of arterioles in the skin
B contraction of hair erector muscles
C decrease in the rate of metabolism
D decrease in production of sweat by glands in the skin

SKILLS INTERPRETATION

3 Construct a table like the one below to show the changes that take place when a person is put in a hot or cold environment. Your table should have three columns.

Changes taking place	Hot environment	Cold environment
sweating		
blood flow through capillary loops		vasoconstriction decreases blood flow through surface capillaries so that less heat is radiated from the skin
hairs in skin		
shivering		
metabolism		

SKILLS ANALYSIS, REASONING

4 Look at the body temperatures of mammals and birds shown in Table 8.2 on page 100. Use the information in the table to answer these questions:

a How does the average temperature of birds differ from the average temperature of mammals? Can you suggest why this is an advantage for birds?

b Is there a relationship between the body temperature of a mammal and the temperature of its habitat? Give an example to support your answer.

c Polar bears have thick white fur covering their bodies. Explain two ways in which this is an adaptation to their habitat (the place where the animal lives).

9 REPRODUCTION IN HUMANS

One of the characteristics of living organisms that makes them different from non-living things is their ability to produce offspring, or **reproduce**. Reproduction is all about an organism passing on its genes. This can be through special sex cells, or gametes. It can also be asexually, without the production of gametes. In this chapter we look at the differences between sexual and asexual reproduction, and study in detail the process of human reproduction.

LEARNING OBJECTIVES

- Understand the differences between sexual and asexual reproduction
- Understand that fertilisation involves the fusion of a male and female gamete to produce a zygote
- Understand that a zygote undergoes cell division and develops into an embryo
- Understand how the structure and function of the human male and female reproductive systems are adapted for their functions
- Describe the role of the placenta in the nutrition of the developing embryo
- Understand how the developing embryo is protected by amniotic fluid
- Understand the roles of oestrogen and testosterone in the development of secondary sexual characteristics
- Understand the roles of oestrogen and progesterone in the menstrual cycle

SEXUAL AND ASEXUAL REPRODUCTION COMPARED

In any method of reproduction, the end result is the production of more organisms of the same species. Humans produce more humans, pea plants produce more pea plants and salmonella bacteria produce more salmonella bacteria. However, the way in which they reproduce differs. There are two types of reproduction: **sexual reproduction** and **asexual reproduction**.

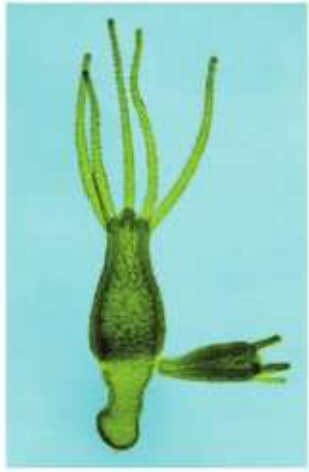
In sexual reproduction, specialised sex cells called **gametes** are produced. There are usually two types, a mobile male gamete called a **sperm** and a stationary female gamete called an egg cell or **ovum** (plural **ova**).



▲ Figure 9.1 A sperm fertilising an egg

The sperm must move to the egg and fuse (join) with it. This is called **fertilisation** (Figure 9.1). The single cell formed by fertilisation is called a **zygote**. This cell will divide many times by mitosis to form all the cells of the new animal.

In asexual reproduction, there are no specialised gametes and there is no fertilisation. Instead, cells in one part of the body divide by mitosis to form a structure that breaks away from the parent body and grows into a new organism. Not many animals reproduce in this way. Figure 9.2 shows *Hydra* (a small animal similar to jellyfish) reproducing by budding. Cells in the body wall divide to form a small version of the adult. This eventually breaks off and becomes a free-living *Hydra*. One animal may produce several 'buds' in a short space of time.



▲ Figure 9.2 *Hydra* reproducing asexually by budding

KEY POINT

Individuals produced asexually from the same adult organism are called **clones**.

KEY POINT

A **gene** is a section of DNA that determines a particular characteristic or feature. Genes are found in the nucleus of a cell on the chromosomes (see Chapter 18).

All the offspring produced from *Hydra* buds are genetically identical – they have exactly the same genes. This is because all the cells of the new individual are produced by **mitosis** from just one cell in the body of the adult. When cells divide by mitosis, the new cells that are produced are exact copies of the original cell (see Chapter 17 for a description of mitosis). As a result, all the cells of an organism that are produced asexually have the same genes as the cell that produced them – the original adult cell. So *all* asexually produced offspring from one adult will have the same genes as the cells of the adult. They will *all* be genetic copies of that adult and so will be identical to each other.

Asexual reproduction is useful to a species when the environment in which it lives is relatively stable. If an organism is well adapted to this stable environment, asexual reproduction will produce offspring that are also well adapted. However, if the environment changes significantly, then *all* the individuals will be affected equally by the change. It may be such a dramatic change that none of the individuals are adapted well enough to survive. The species will die out in that area.

SEXUAL REPRODUCTION

There are four stages in any method of sexual reproduction.

- Gametes (sperm and egg cells) are produced.
- The male gamete (sperm) is transferred to the female gamete (egg cell).
- Fertilisation must occur – the sperm fuses with the egg.
- The zygote formed develops into a new individual.

The offspring produced by sexual reproduction show a great deal of genetic variation as a result of both gamete production and fertilisation.

PRODUCTION OF GAMETES

Sperm are produced in the male sex organs – the testes. Eggs are produced in the female sex organs – the ovaries. Both are produced when cells inside these organs divide. These cells do not divide by mitosis but by **meiosis** (see Chapter 17). Meiosis produces cells that are not genetically identical and have only half the number of chromosomes as the original cell.

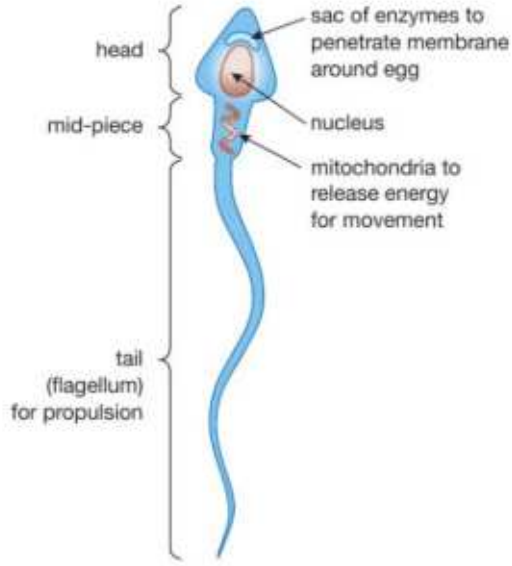
KEY POINT

Cells that have the full number of chromosomes are called **diploid** cells. Cells that only have half the normal number of chromosomes are called **haploid** cells.

TRANSFER OF THE SPERM TO THE EGG

Sperm are specialised for swimming. They have a tail-like **flagellum** that moves them through a fluid. Figure 9.3 shows the structure of a sperm.

Some male animals, such as those of most fish, release their sperm into the water in which they live. The female animals release their eggs into the water and the sperm then swim through the water to fertilise the eggs. This is called *external* fertilisation as it takes place *outside* the body. Before the release takes place, there is usually some mating behaviour to ensure that male and female are in the same place at the same time. This gives the best chance of fertilisation occurring before water currents sweep the sex cells away.



▲ Figure 9.3 The structure of a sperm

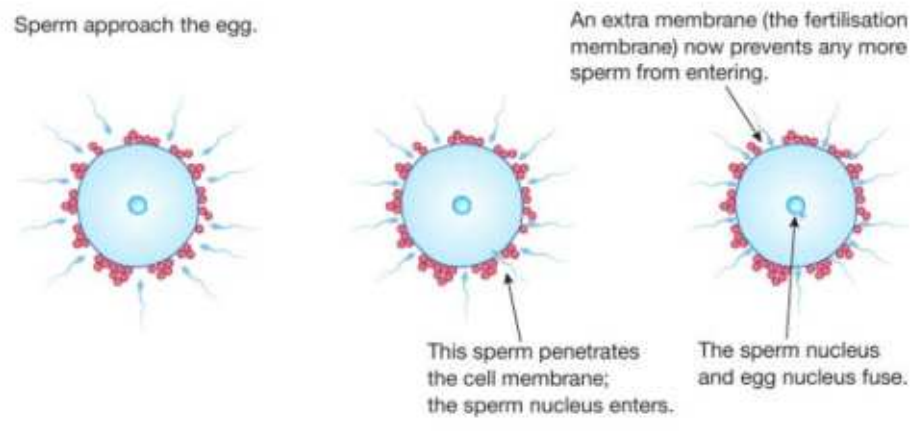
Other male animals, such as those of birds and mammals, ejaculate their sperm in a special fluid into the bodies of the females. *Internal* fertilisation then takes place *inside* the female's body. Fertilisation is much more likely as there are no external factors to prevent the sperm from reaching the eggs. Some form of **sexual intercourse** precedes **ejaculation**.

FERTILISATION

REMINDER

Red blood cells are exceptions. They have no nucleus, so have no chromosomes.

Once the sperm has reached the egg, its nucleus must enter the egg and fuse with the egg nucleus. As each gamete has only half the normal number of chromosomes, the zygote formed by fertilisation will have the full number of chromosomes. In humans, the sperm and egg each have only 23 chromosomes. The zygote has 46 chromosomes, like all other cells in the body. Figure 9.4 shows the main stages in fertilisation.

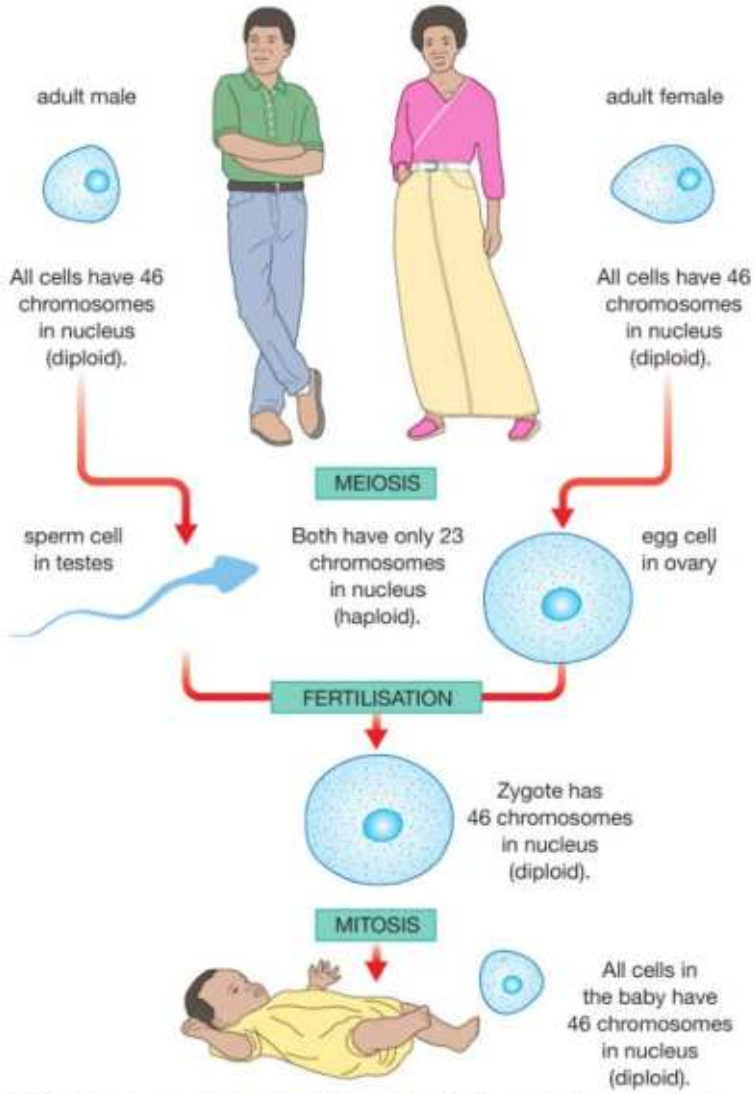


▲ Figure 9.4 The main stages in fertilisation

Fertilisation does more than just restore the diploid chromosome number; it provides an additional source of genetic variation. The sperm and eggs are all genetically different because they are formed by meiosis. Therefore, each time fertilisation takes place, it brings together a different combination of genes.

SUMMARY OF THE HUMAN LIFE CYCLE

Each zygote that is formed must divide to produce all the cells that will make up the adult. All these cells must have the full number of chromosomes, so the zygote divides repeatedly by mitosis. Figure 9.5 shows the importance of meiosis, mitosis and fertilisation in the human life cycle.



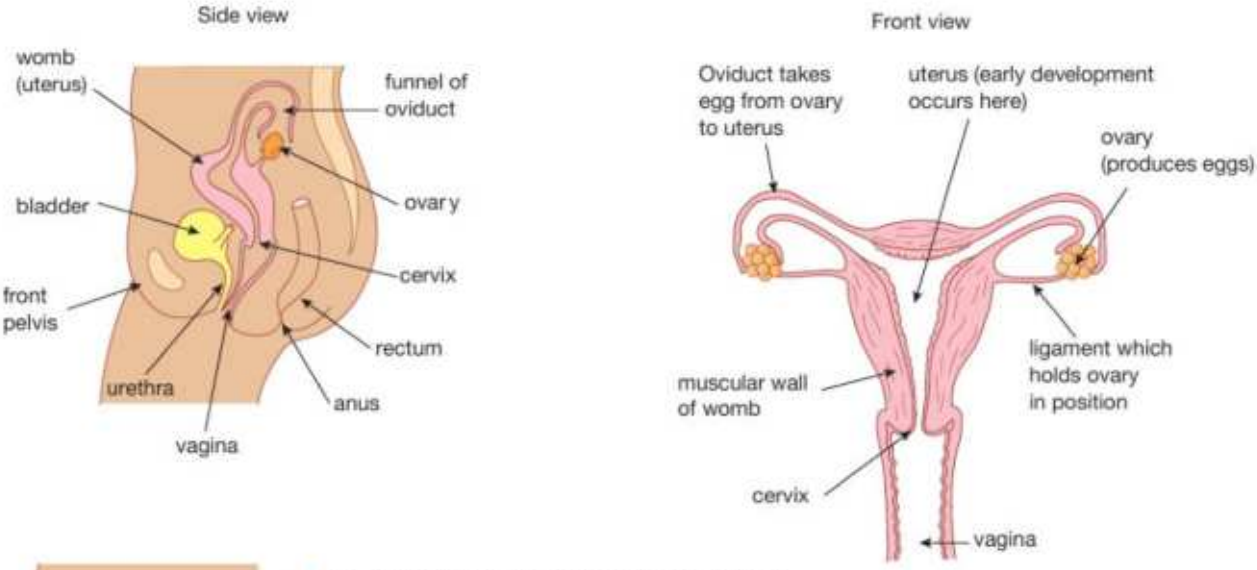
▲ Figure 9.5 The importance of meiosis, mitosis and fertilisation in the human life cycle.

Mitosis is not the only process involved in development, otherwise all that would be produced would be a ball of cells. During the process, cells move around and different shaped structures are formed. Also, different cells specialise to become bone cells, nerve cells, muscle cells, and so on (the process called **differentiation**).

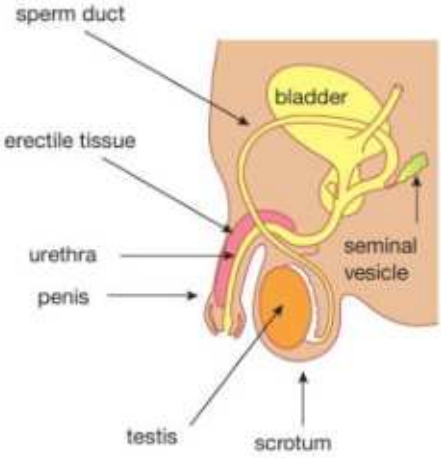
REPRODUCTION IN HUMANS

Humans reproduce sexually and fertilisation is internal. Figures 9.6 and 9.7 show the structure of the human female and male reproductive systems.

The sperm are produced in the testes by meiosis. During sexual intercourse, they pass along the sperm duct and are mixed with a fluid from the seminal vesicles. This mixture, called **semen**, is ejaculated through the **urethra** into the vagina of the female. The sperm then begin to swim towards the oviducts.

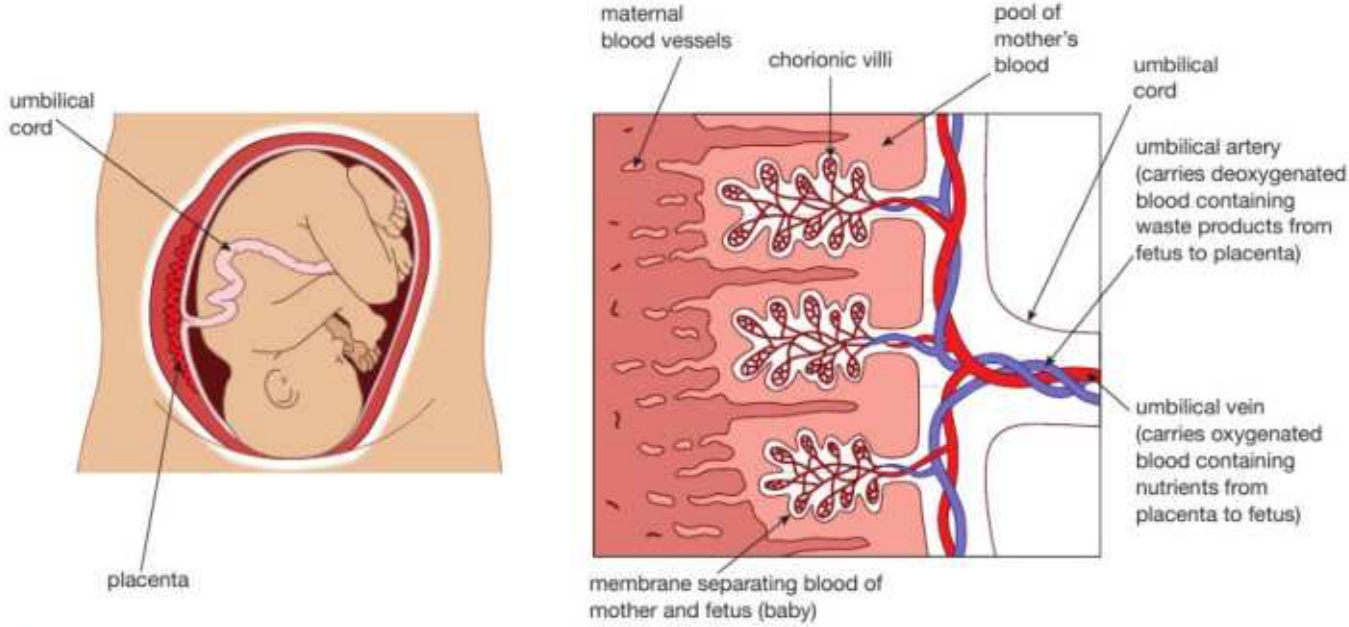


▲ Figure 9.6 The human female reproductive system



▲ Figure 9.7 The human male reproductive system.

Each month, an egg is released into an **oviduct** from one of the ovaries. (The oviduct is also known as the Fallopian tube.) This is called **ovulation**. If an egg is present in the oviduct, then it may be fertilised by sperm introduced during intercourse. The zygote formed will begin to develop into an **embryo**, which will implant in the lining of the uterus. Here, the embryo will develop a **placenta**, which will allow the embryo to obtain materials such as oxygen and nutrients from the mother's blood. It also allows the embryo to get rid of waste products such as urea and carbon dioxide, as well as anchoring the embryo in the uterus. The placenta secretes female hormones, in particular **progesterone**, which maintain the pregnancy and prevent the embryo from aborting (being rejected by the mother's body). Figure 9.8 shows the structure and position of the placenta.



▲ Figure 9.8 The position of the fetus just before birth, and the structure of the placenta.

DID YOU KNOW?

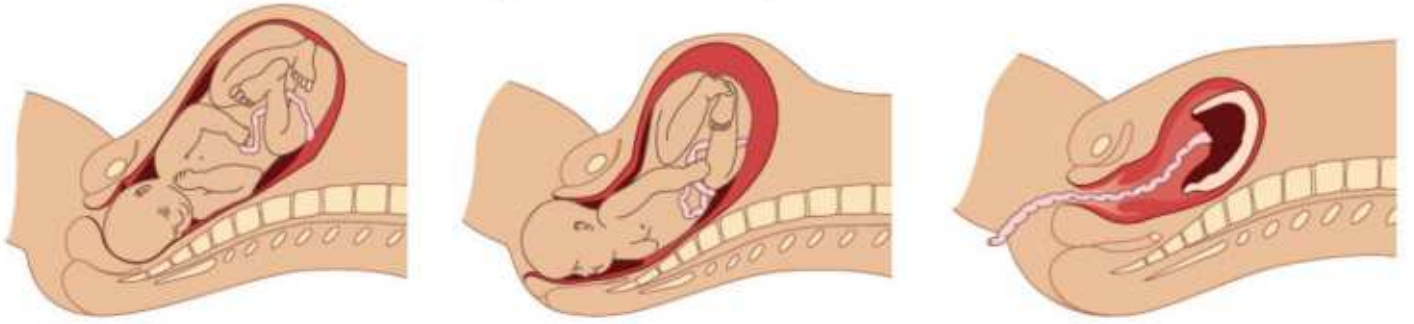
Just before birth, the fetus takes up so much room that many of the mother's organs are moved out of position. The heart is pushed upwards and rotates so that the base points towards the left breast.

During pregnancy, a membrane called the **amnion** encloses the developing embryo. The amnion secretes a fluid called **amniotic fluid**, which protects the developing embryo against sudden movements and bumps. As the embryo develops, it becomes more and more complex. When it becomes recognisably human, we no longer call it an embryo but a **fetus**. At the end of nine months of development, there just isn't any room left for the fetus to grow and it sends a hormonal 'signal' to the mother to begin the birth process. Figure 9.8 also shows the position of a human fetus just before birth.

There are three stages to the birth of a child.

1. **Dilation of the cervix**. The **cervix** is the 'neck' of the uterus. It gets wider to allow the baby to pass through. The muscles of the uterus contract quite strongly and tears the amnion, allowing the amniotic fluid to escape. (In some countries the woman describes this as 'her waters have broken'.)
2. **Delivery of the baby**. Strong contractions of the muscles of the uterus push the baby's head through the cervix and then through the vagina to the outside world.
3. **Delivery of the afterbirth**. After the baby has been born, the uterus continues to contract and pushes the placenta out, together with the membranes that surrounded the baby. These are known as the afterbirth.

Figure 9.9 shows the stages of birth.



1 Baby's head pushes cervix; mucous plug dislodges and waters break.

2 Uterus contracts to push baby out through the vagina.

3 The placenta becomes detached from the wall of the uterus and is expelled through the vagina as the afterbirth.

▲ Figure 9.9 The stages of birth

HORMONES CONTROLLING REPRODUCTION

Most animals are unable to reproduce when they are young. We say that they are sexually immature. When a baby is born, it is recognisable as a boy or girl by its sex organs.

DID YOU KNOW?

Sperm production is most efficient at a temperature of about 34 °C, just below the core body temperature (37 °C). This is why the testes are outside the body in the scrotum, where the temperature is a little lower.

The presence of male or female sex organs is known as the primary sex characteristics. During their teens, changes happen to boys and girls that lead to sexual maturity. These changes are controlled by hormones, and the time when they happen is called **puberty**. Puberty involves two developments. The first is that the gametes (eggs and sperm) start to mature and be released. The second is that the bodies of both sexes adapt to allow reproduction to take place. These events are started by hormones released by the pituitary gland.

In boys, these pituitary hormones stimulate sperm production and instruct the testes to secrete the male sex hormone, **testosterone**. Testosterone controls the development of the male **secondary sexual characteristics**. These include growth of the penis and testes, growth of facial and body hair, muscle

development and breaking of the voice (Table 9.1).

In girls, the pituitary hormones control the release of a female sex hormone called **oestrogen**, from the ovaries. Oestrogen produces the female secondary sexual characteristics, such as breast development and the beginning of menstruation ('periods').

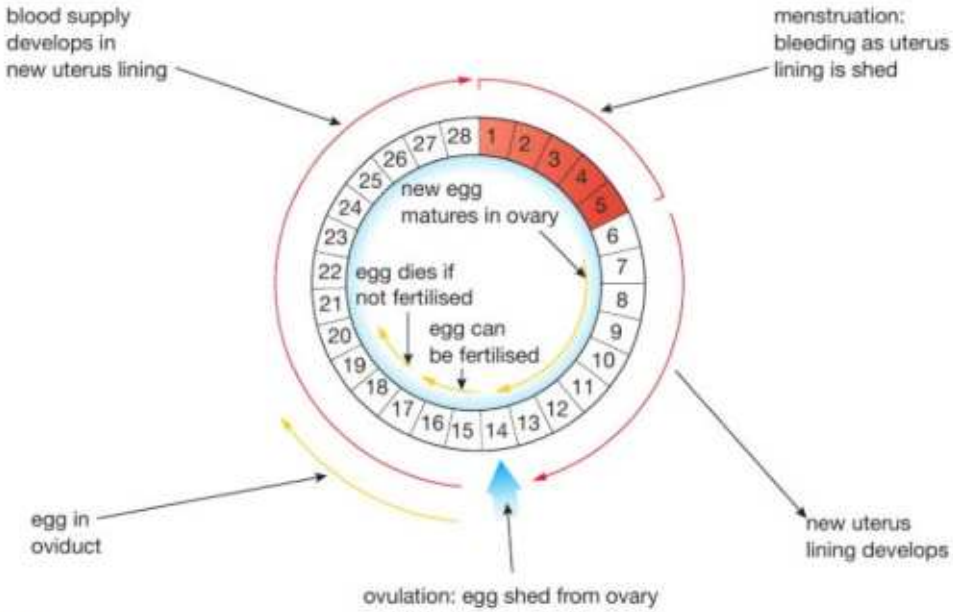
Table 9.1 Changes at puberty.

In boys	In girls
sperm production starts	the menstrual cycle begins, and eggs are released by the ovaries every month
growth and development of male sexual organs	growth and development of female sexual organs
growth of armpit and pubic hair, and chest and facial hair (beard)	growth of armpit and pubic hair
increase in body mass; growth of muscles, e.g. chest	increase in body mass; development of 'rounded' shape to hips
voice breaks	voice deepens without sudden 'breaking'
sexual 'drive' develops	sexual 'drive' develops
	breasts develop

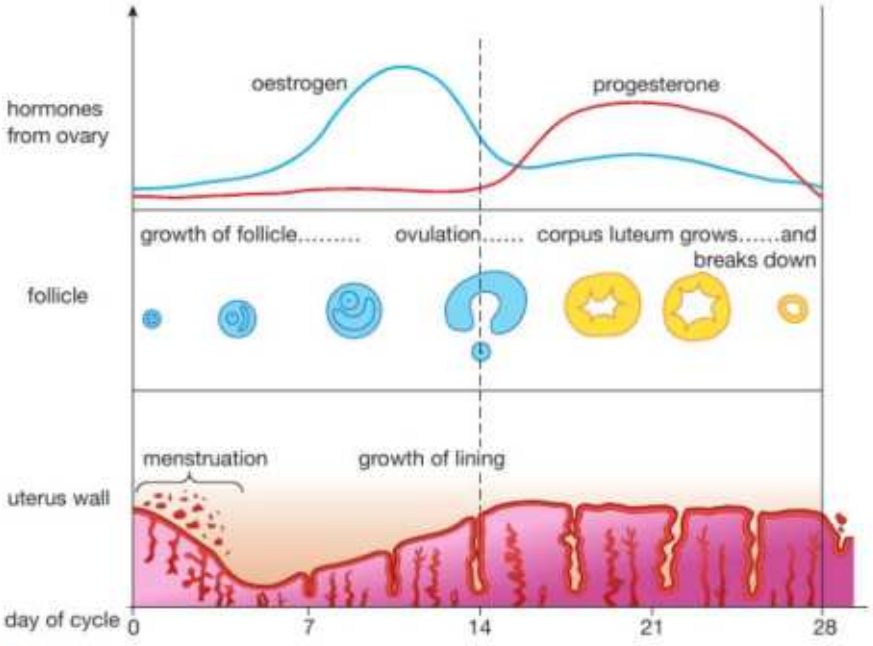
The age when puberty takes place can vary a lot, but it is usually between about 11 and 14 years in girls and 13 and 16 years in boys. It takes several years for puberty to be completed. Some of the most complex changes take place in girls, with the start of menstruation.

HORMONES AND THE MENSTRUAL CYCLE

'Menstrual' means 'monthly', and in most women the **menstrual cycle** takes about a month, although it can vary from as little as two weeks to as long as six weeks (Figures 9.10 and 9.11). In the middle of the cycle is an event called **ovulation**, which is the release of a mature egg cell, or egg.



▲ Figure 9.10 The menstrual cycle



▲ Figure 9.11 Changes taking place during the menstrual cycle

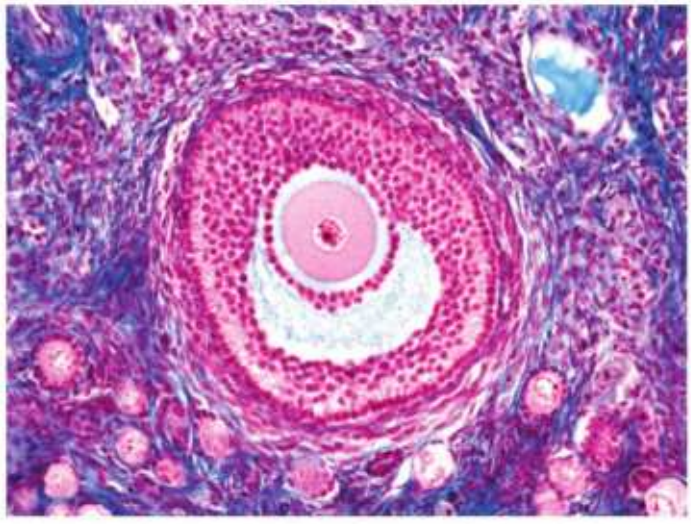
One function of the cycle is to control the development of the lining of the uterus (womb), so that if the egg is fertilised, the lining will be ready to receive the fertilised egg. If the egg is not fertilised, the lining of the uterus is lost from the woman's body as the flow of menstrual blood and cells of the lining, called a **period**.

A cycle is a continuous process, so it doesn't really have a beginning, but the first day of menstruation is usually called day 1.

Inside a woman's ovaries are hundreds of thousands of cells that could develop into mature eggs. Every month, one of these grows inside a ball of cells called a **follicle** (Figure 9.12). At the middle of the cycle (about day 14) the follicle moves towards the edge of the **ovary** and the egg is released as the follicle bursts open. This is the moment of ovulation.

DID YOU KNOW?

A small percentage of women are able to sense the exact moment that ovulation happens, as the egg bursts out of an ovary.



▲ Figure 9.12 Eggs developing inside the follicles of an ovary. The large follicle contains a fully developed egg ready for ovulation.

While this is going on, the lining of the uterus has been repaired after menstruation, and has thickened. This change is brought about by the hormone oestrogen, which is secreted by the ovaries.

EXTENSION WORK

'Corpus luteum' is Latin for 'yellow body'. A corpus luteum appears as a large yellow swelling in an ovary after the egg has been released.

After the egg has been released, it travels down the oviduct to the uterus. It is here in the oviduct that fertilisation may happen, if sexual intercourse has taken place. What's left of the follicle now forms a structure in the ovary called the **corpus luteum**. The corpus luteum makes another hormone called **progesterone**. Progesterone completes the development of the uterus lining, by thickening and maintaining it, ready for the fertilised egg to sink into it and develop into an embryo.

If the egg is not fertilised, the corpus luteum breaks down and stops making progesterone. The lining of the uterus then passes out through the woman's vagina during menstruation. If, however, the egg is fertilised, the corpus luteum carries on making progesterone, the lining is not shed, and menstruation doesn't happen. The first sign that tells a woman she is pregnant is when her monthly periods stop. Later on in pregnancy, the **placenta** secretes progesterone, taking over the role of the corpus luteum.

CHAPTER QUESTIONS

More questions on human reproduction can be found at the end of Unit 2 on page 116.

SKILLS CRITICAL THINKING

1 Which of the following describes sex cells (gametes)?

A diploid cells produced by meiosis

B diploid cells produced by mitosis

C haploid cells produced by meiosis

D haploid cells produced by mitosis

2 Which of the following is *not* a function of the ovaries?

A the secretion of progesterone

B the production of eggs

C the secretion of oestrogen

D the site of fertilisation

3 Which of the following organs produce(s) the hormone progesterone?

1. pituitary gland
2. ovary
3. uterus
4. placenta

A 1 and 2

B 2 and 3

C 3 and 4

D 2 and 4

SKILLS CRITICAL THINKING

4 A woman's first day of menstruation was on 1st June. Assuming she has a 28-day menstrual cycle, when was she most likely to ovulate?

A 7 June

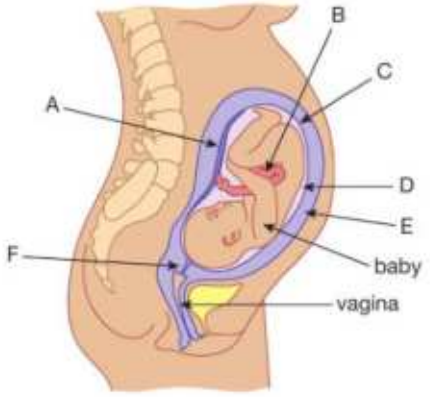
B 10 June

C 14 June

D 21 June

SKILLS ANALYSIS

5 The diagram shows a baby about to be born.



a Name parts A to F on the diagram.

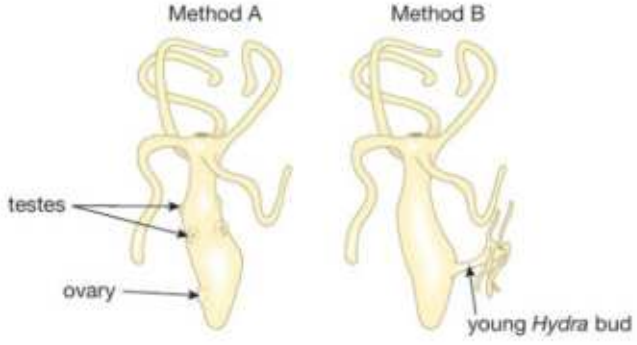
b What is the function of A during pregnancy?

c What must happen to D and E just before birth?

d What must E and F do during birth?

SKILLS CRITICAL THINKING

6 The diagram shows *Hydra* (a small water animal) reproducing in two ways.



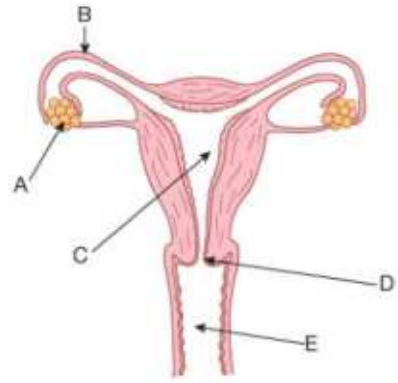
a Which of the two methods shows asexual reproduction? Give a reason for your answer.

b Explain why organisms produced asexually are genetically identical to each other and to the organism that produced them.

c When the surroundings do not change for long periods, *Hydra* reproduces mainly asexually. When the conditions change, *Hydra* begins to reproduce sexually. How does this pattern of sexual and asexual reproduction help *Hydra* to survive?

SKILLS ANALYSIS

7 a The diagram shows the female reproductive system.



Which letter represents:

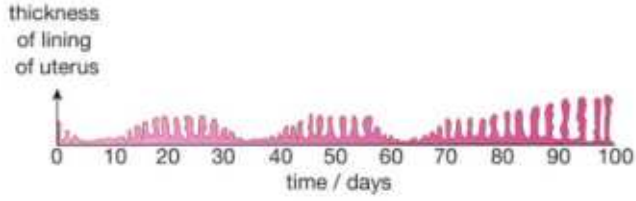
i the site of production of oestrogen and progesterone

ii the structure where fertilisation usually occurs

iii the structure that must dilate when birth commences

iv the structure that releases ova?

b The graph shows the changes in the thickness of the lining of a woman's uterus over 100 days.



SKILLS CRITICAL THINKING

i Name the hormone that causes the thickening of the uterine lining.

SKILLS INTERPRETATION

ii Use the graph to determine the duration of *this* woman's menstrual cycle. Explain how you arrived at your answer.

iii From the graph, deduce the approximate day on which fertilisation leading to pregnancy took place. Explain how you arrived at your answer.

SKILLS CRITICAL THINKING

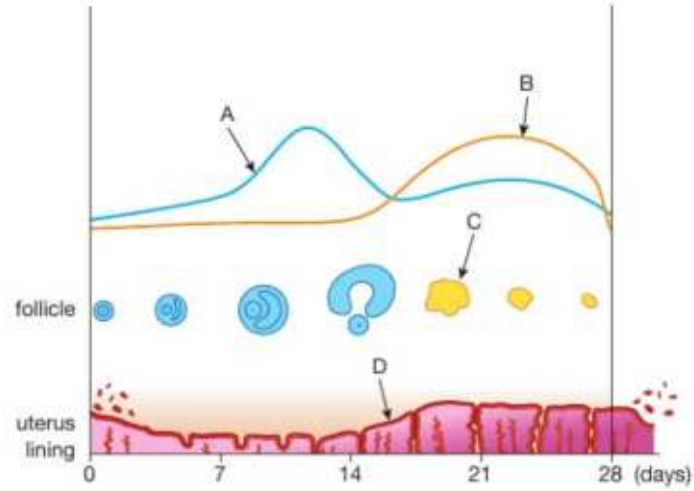
iv Why must the uterus lining remain thickened throughout pregnancy?

SKILLS INTERPERSONAL SKILLS

8 The number of sperm cells per cm^3 of semen (the fluid containing sperm) is called the 'sperm count'. Some scientists believe that over the last 50 years, the sperm counts of adult male humans have decreased. They think that this is caused by a number of factors, including drinking water polluted with oestrogens and other chemicals. Carry out an Internet search to find out the evidence for this. Summarise your findings in about two sides of A4 paper.

SKILLS ANALYSIS

9 The graph shows some of the changes taking place during the menstrual cycle.



a Identify the two hormones produced by the ovary, which are shown by the lines A and B on the graph.

b Name the structure C.

c What is the purpose of the thickening of the uterus lining at D?

d When is sexual intercourse most likely to result in pregnancy: at day 6, 10, 13, 20 or 23?

e Why is it important that the level of progesterone remains high in the blood of a woman during pregnancy? How does her body achieve this:

SKILLS REASONING

i just after she becomes pregnant

ii later on in pregnancy?

UNIT QUESTIONS

SKILLS CRITICAL THINKING

1

The table shows the percentage of gases in inhaled and exhaled air.

Gas	Inhaled air / %	Exhaled air / %
nitrogen	78	79
oxygen		
carbon dioxide		
other gases (mainly argon)	1	1

a Copy the table and fill in the gaps by choosing from the following numbers:

21 4 0.04 16 **(2)**

SKILLS REASONING

b Explain why the percentage of carbon dioxide is different in inhaled and exhaled air. **(2)**

c Explain why exhaling is a form of excretion. **(2)**

d The following features can be seen in the lungs:

i thin membranes between the alveoli and the blood supply

ii a good blood supply

iii a large surface area.

In each case explain how the feature helps gas exchange to happen quickly. **(6)**

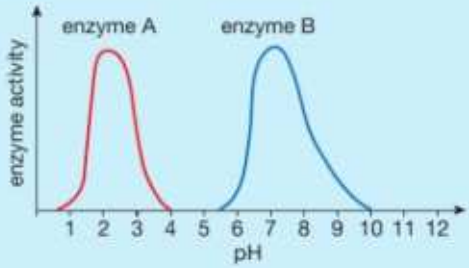
(Total 12 marks)

SKILLS ANALYSIS

2

Digestion is brought about by enzymes converting large insoluble molecules into smaller soluble molecules that can be more easily absorbed.

a The activity of enzymes is influenced by pH and temperature. The graph shows the activity of two human enzymes from different regions of the gut at different pH values.



i Suggest which regions of the gut the two enzymes come from. Explain your answer. **(4)**

ii Which nutrient does enzyme A digest? **(1)**

b Farmers sometimes include urea in cattle food. The microorganisms in the rumen can use urea to make protein.

SKILLS CRITICAL THINKING

i In mammals, where in the body is urea made? **(1)**

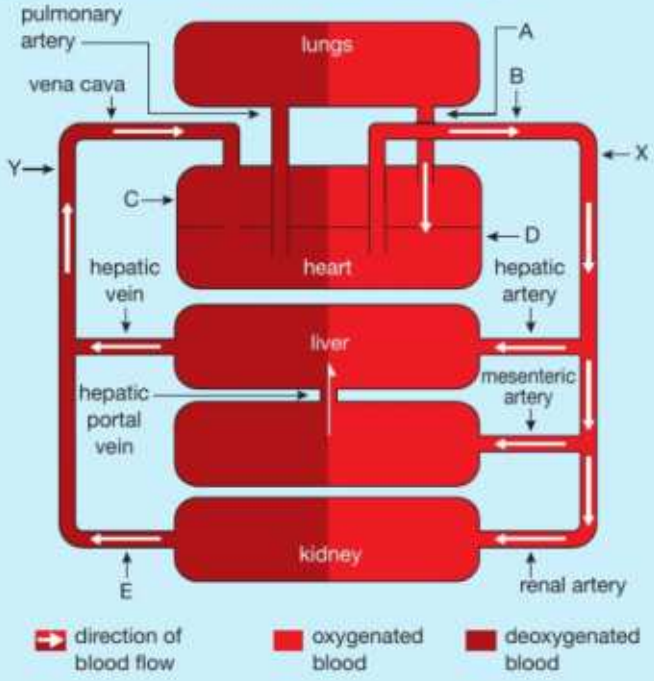
ii What is urea made from? **(1)**

iii Suggest how feeding urea to cattle can result in an increased growth rate. **(1)**

(Total 8 marks)

SKILLS ANALYSIS

3 The diagram shows the human circulatory system. The system carries nutrients, oxygen and carbon dioxide around the body.



a Write down the names of the structures labelled A to E. **(5)**

b Give two differences between the blood vessels at point X and point Y. **(2)**

c During exercise, the adrenal gland releases the hormone adrenaline. Reflexes involving the medulla of the brain influence the heartbeat and breathing.

SKILLS CRITICAL THINKING

i Describe two effects of adrenaline on the heartbeat. **(2)**

ii Describe two other effects of adrenaline on the body. **(2)**

SKILLS REASONING

d How is a reflex action different from a voluntary action? **(2)**

e Following exercise there is a recovery period in which breathing rate and heart rate gradually return to pre-exercise levels. Explain why they do not return immediately to these levels. **(3)**

(Total 16 marks)

SKILLS INTERPRETATION

4 The immune system responds to infections using white blood cells. A phagocyte is one type of white blood cell.

a Draw and label a phagocyte. **(3)**

SKILLS CRITICAL THINKING

b State one way that the structure of a phagocyte differs from that of a red blood cell. **(1)**

c Phagocytes carry out phagocytosis. Describe this process. **(2)**

d Describe how other white blood cells are involved in the immune response. **(3)**

(Total 9 marks)

SKILLS REASONING

5 Humans and other mammals are able to maintain a constant body temperature which is usually higher than that of their surroundings.

a Explain the advantage in maintaining a constant, high body temperature. **(1)**

b The temperature of the blood is constantly monitored by the brain. If it detects a drop in blood temperature, the following things happen: the arterioles leading to the skin capillaries constrict, less sweat is formed and shivering begins.

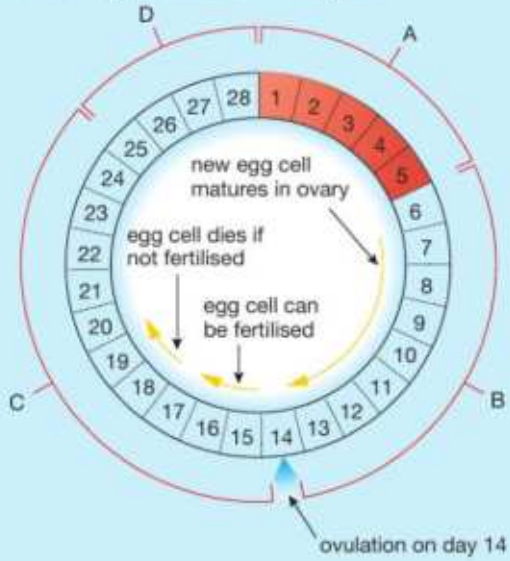
i Explain how each response helps the body to keep warm. **(3)**

ii Explain how the structure of arterioles allows them to constrict. **(2)**

(Total 6 marks)

SKILLS ANALYSIS

6 The diagram represents a typical menstrual cycle.



a Using evidence from the diagram, answer the following questions.

During which of the stages A, B, C or D does:

i the level of the hormone oestrogen increase in the blood

ii the level of the hormone progesterone increase in the blood

iii the uterine lining become more vascular

iv the levels of oestrogen and progesterone in the blood fall

v the uterine lining begin to break down? **(5)**

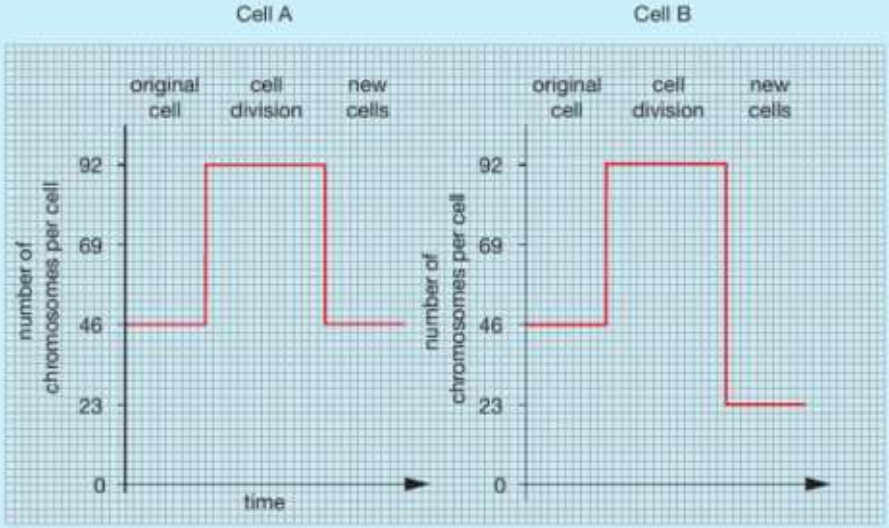
SKILLS REASONING

b Explain how knowledge of the menstrual cycle can be used to avoid pregnancy. **(3)**

(Total 8 marks)

SKILLS CRITICAL THINKING

7 Cells can divide by mitosis or by meiosis. Human cells contain 46 chromosomes. The graphs show the changes in the number of chromosomes per cell as two different human cells undergo cell division.



a Which of the two cells, A or B, is dividing by meiosis? Explain how you arrived at your answer. **(3)**

b Explain the importance of meiosis, mitosis and fertilisation in maintaining the human chromosome number constant at 46 chromosomes per cell, generation after generation. **(6)**

c Give *three* differences between mitosis and meiosis. **(3)**

(Total 12 marks)

SKILLS EXECUTIVE FUNCTION

8 Protein supplements are foods that some body-builders use to increase the growth of their muscles. Describe an investigation to find out if adding a protein supplement to the diet of rats will increase their growth.

Your answer should include experimental details and be written in full sentences. **(6)**

(Total 6 marks)

PLANTS AND FOOD 121
TRANSPORT IN PLANTS 136
CHEMICAL COORDINATION IN PLANTS 145
REPRODUCTION IN PLANTS 151

BIOLOGY UNIT 3 PLANT PHYSIOLOGY

Plant physiology is the branch of biology that deals with the internal activities of plants. It covers many aspects of plant life, including nutrition (photosynthesis), movement of materials around the plant, and reproduction. There are many reasons why we need to study how plants work, not least because they provide the world's food supply and oxygen. Animals, including humans, could not exist without plants. Modern agriculture depends on the scientific study of plant physiology, as does our understanding of eccosystems.



10 PLANTS AND FOOD

This chapter looks at photosynthesis, the process by which plants make starch, and the structure of leaves in relation to photosynthesis. It also deals with how plants obtain other nutrients, and their uses in the plant.

LEARNING OBJECTIVES

- Investigate photosynthesis by testing for the production of starch in a leaf
- Investigate the need for light, carbon dioxide and chlorophyll for photosynthesis
- Understand the process of photosynthesis and its importance in the conversion of light energy to chemical energy
- Know the word equation and the balanced symbol equation for photosynthesis
- Describe the structure of the leaf and explain how it is adapted for photosynthesis
- Understand how light intensity, carbon dioxide concentration and temperature affect the rate of photosynthesis
- Investigate photosynthesis using the evolution of oxygen from a water plant
- Understand that plants require mineral ions for growth, and that magnesium ions are needed to make chlorophyll and nitrate ions are needed to make amino acids

PLANTS MAKE STARCH

All the foods shown in Figure 10.1 are products of plants. Some, such as potatoes, rice and bread (made from cereals such as wheat or rye), form the staple diet of humans. They all contain starch, which is the main storage carbohydrate made by plants. Starch is a good way of storing carbohydrate because it insoluble, compact and can be broken down easily.



▲ Figure 10.1 All these foods are made by plants or made from products of plants. They all contain starch.

ACTIVITY 1

▼ PRACTICAL: TESTING LEAVES FOR STARCH

You can test for starch in food by adding a few drops of yellow-brown iodine solution (see Chapter 4). If the food contains starch, a blue-black colour is produced.

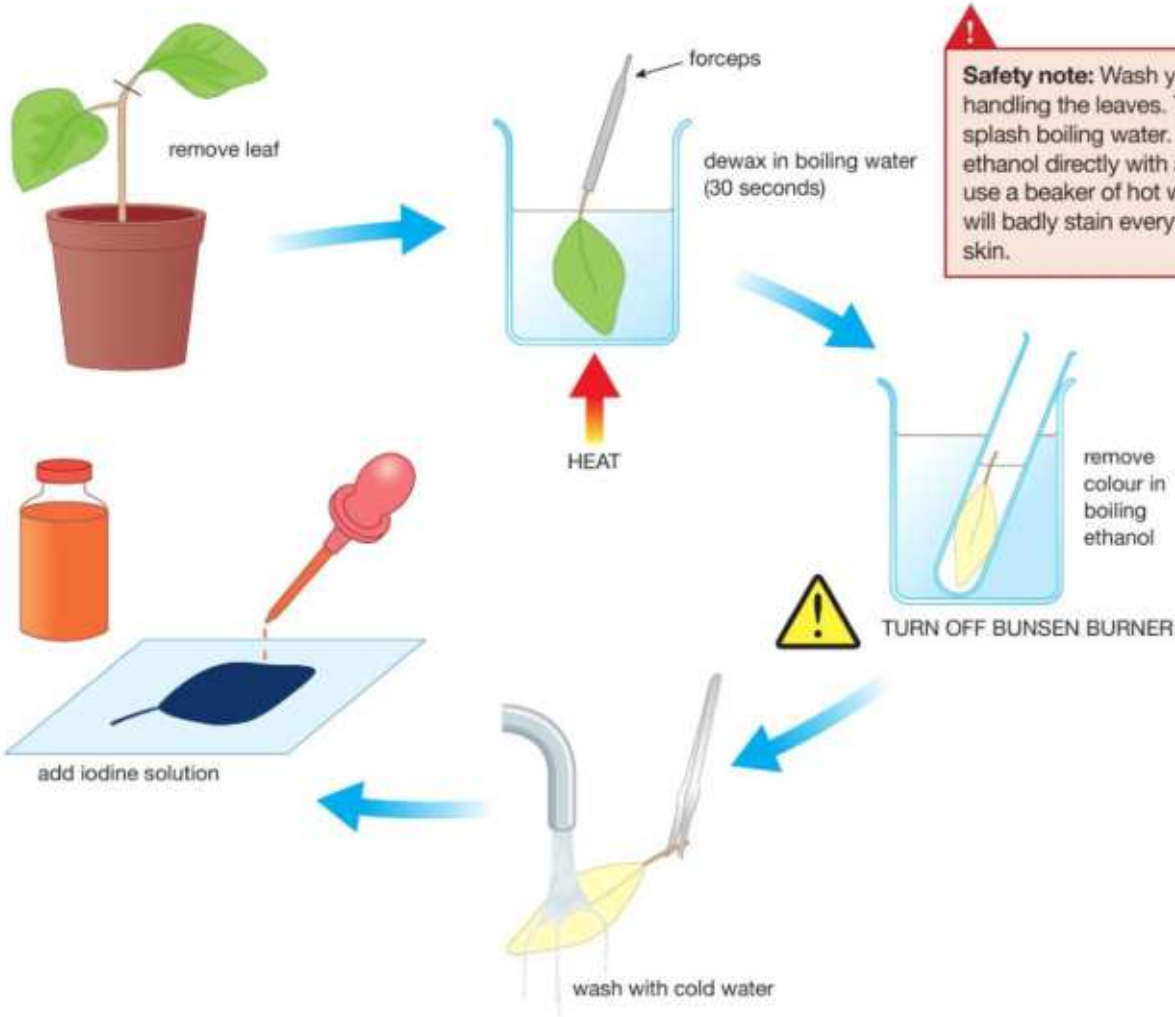
Leaves that have been in sunlight also contain starch, but you can't test for it by adding iodine solution to a fresh leaf. The outer waxy surface of the leaf will not absorb the solution, and besides, the green colour of the leaf would hide the colour change. To test for starch in a leaf, the outer waxy layer needs to be removed and the leaf decolourised. This is done by placing the leaf in boiling ethanol (see Figure 10.2).

A beaker of water is set up on a tripod and gauze and the water heated until it boils. A leaf is removed from a plant and killed by placing it in boiling water for 30 seconds (this stops all chemical reactions in the leaf).

The Bunsen burner is turned off (this is important because ethanol is highly flammable), the leaf is placed in a boiling tube containing ethanol, and the tube is placed in the beaker of hot water. The boiling point of ethanol (about 78 °C) is lower than that of water (100 °C) so the ethanol will boil for a few minutes, until the water cools down. This is long enough to remove most of the chlorophyll from the leaf.

When the leaf has turned colourless or pale yellow, it is removed and washed in cold water to soften it, then spread out on a tile and covered with a few drops of iodine solution. After a few minutes, any parts of the leaf that contain starch will turn a dark blue-black colour. This only works if the plant has had plenty of light for some hours before the test.

Safety note: Wash your hands after handling the leaves. Take care not to splash boiling water. Do not heat the ethanol directly with any flame: instead use a beaker of hot water. Iodine solution will badly stain everything – including skin.

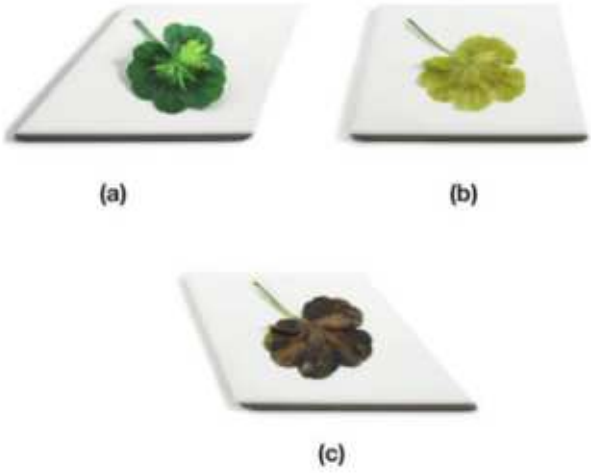


▲ Figure 10.2 How to test a leaf for starch

KEY POINT

You can 'de-starch' a plant by placing it in the dark for 2 or 3 days. The plant uses up the starch stores in its leaves. De-starched plants are used to find out the conditions needed for the plant to make more starch by photosynthesis.

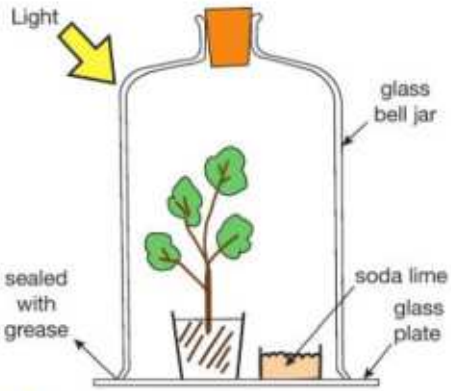
Starch is only made in the parts of plants that contain chlorophyll. You can show this by testing a leaf from a variegated plant, which has green and white areas to its leaves. The white parts of the leaf will give a negative starch test, staining yellow-brown with iodine solution. Only the green areas will stain blue-black. Figure 10.3 shows the results of a starch test on a leaf. The leaf was taken from a plant that had been under a bright light for 24 hours.



▲ Figure 10.3 Testing a leaf for starch. (a) Leaf before test (b) Decolourised leaf (c) Leaf after test, stained blue-black with iodine solution.

HINT

You might think that the results of the test on the variegated leaf prove that chlorophyll is needed for photosynthesis. But is this conclusion fully justified? The leaf could have photosynthesised in the white areas and the sugars been transported elsewhere in the plant. Similarly, the green areas may not be photosynthesising at all, but simply laying down starch from glucose made somewhere else. All it really shows is that starch is present in the green areas and not in the white areas of the leaf. We *assume* this is because chlorophyll is needed for photosynthesis.



▲ Figure 10.4 Demonstration that carbon dioxide is needed for photosynthesis. The soda lime absorbs carbon dioxide from the air in the bell jar. A Control experiment should be set up, using exactly the same apparatus but without the soda lime.

Taking away the source of light is not the only way you can prevent a plant making starch in its leaves. You can also place it in a closed container containing a chemical called soda lime (Figure 10.4). This substance absorbs carbon dioxide from the air around the plant. If the plant is kept under a bright light but with no carbon dioxide, it again won't be able to make starch.

WHERE DOES THE STARCH COME FROM?

You have now found out three important facts about starch production by leaves:

- it uses carbon dioxide from the air
- it needs light
- it needs chlorophyll in the leaves.

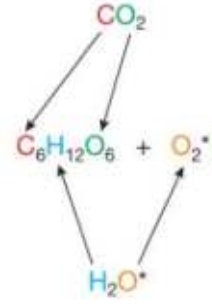
As well as starch, there is another product of this process which is essential to the existence of most living things on the Earth – oxygen. When a plant is in the light, it makes oxygen gas. You can show this using an aquatic plant such as *Elodea* (Canadian pondweed). When a piece of this plant is placed in a test tube of water under a bright light, it produces a stream of small bubbles. If the bubbles are collected and their contents analysed, they are found to contain a high concentration of oxygen (Figure 10.5).



▲ Figure 10.5 The bubbles of gas released from this pondweed contain a higher concentration of oxygen than in atmospheric air.

Starch is composed of long chains of glucose (see Chapter 4). A plant does not make starch directly, but first produces glucose, which is then joined together in chains to form starch molecules. A carbohydrate made of many sugar sub-units is called a **polysaccharide**. Glucose has the formula $C_6H_{12}O_6$. The carbon and oxygen atoms of the glucose molecule come from the carbon dioxide gas in the air around the plant. The hydrogen atoms come from another molecule essential to the living plant – water.

It would be very difficult in a school laboratory to show that a plant uses water to make starch. If you deprived a plant of water in the same way as you deprived it of carbon dioxide, it would soon wilt and eventually die. However, scientists have proved that water is used in photosynthesis. They have done this by supplying the plant with water with 'labelled' atoms, for example using the 'heavy' isotope of oxygen (^{18}O). This isotope ends up in the oxygen gas produced by the plant. A summary of the sources of the atoms in the glucose and oxygen looks like this:



(*oxygen labelled with ^{18}O)

EXTENSION WORK

Isotopes are forms of the same element with the same atomic number but different mass numbers (due to extra neutrons in the nucleus). Isotopes of some elements are radioactive and can be used as 'labels' to follow chemical pathways. Others like ^{18}O are identified by their mass.

PHOTOSYNTHESIS

Plants use the simple inorganic molecules carbon dioxide and water, in the presence of chlorophyll and light, to make glucose and oxygen. This process is called **photosynthesis**.

It is summarised by the equation:

$$\text{carbon dioxide + water} \xrightarrow{\text{light}} \text{glucose + oxygen}$$

$$\text{or: } 6CO_2 + 6H_2O \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

DID YOU KNOW?

The 'photo' in photosynthesis comes from the Greek word *photos*, meaning light, and a 'synthesis' reaction is one where small molecules are built up into larger ones.

The role of the green pigment, chlorophyll, is to absorb the light energy needed for the reaction to take place. The products of the reaction (glucose and oxygen) contain more energy than the carbon dioxide and water. In other words, photosynthesis converts light energy into chemical energy.

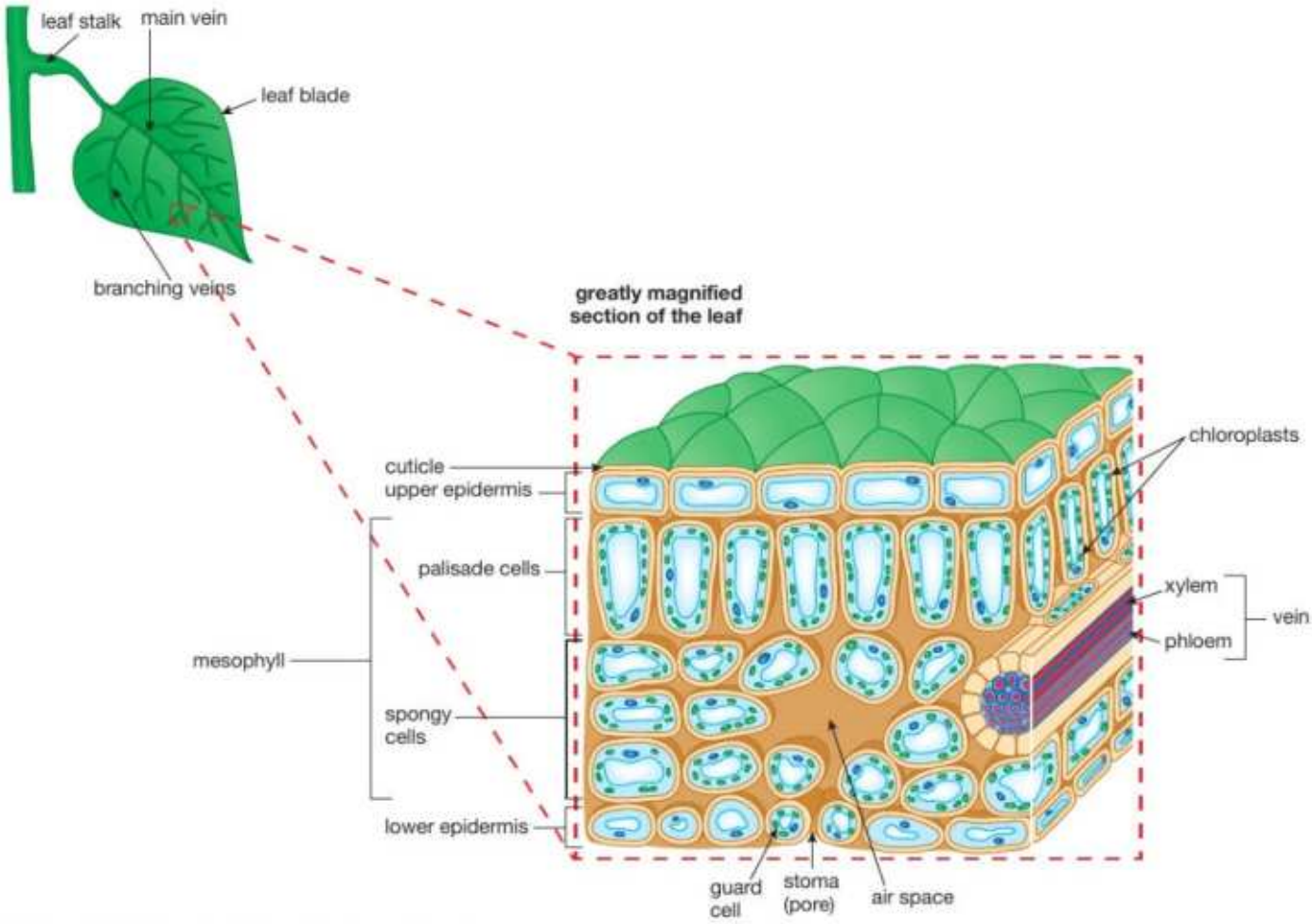
You will probably have noticed that the overall equation for photosynthesis is the reverse of the one for aerobic respiration (see Chapter 1):

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \quad \text{(plus energy)}$$

Respiration, which is carried out by both animals and plants, *releases* energy (but not as light) from the breakdown of glucose. The chemical energy in the glucose came originally from light 'trapped' by the process of photosynthesis.

THE STRUCTURE OF LEAVES

Most green parts of a plant can photosynthesise, but the leaves are the plant organs which are best adapted for this function. To be able to photosynthesise efficiently, leaves need to have a large surface area to absorb light, many chloroplasts containing the chlorophyll, a supply of water and carbon dioxide, and a system for carrying away the products of photosynthesis to other parts of the plant. They also need to release oxygen (and water vapour) from the leaf cells. Most leaves are thin, flat structures supported by a leaf stalk which can grow to allow the blade of the leaf to be angled to receive the maximum amount of sunlight (Figure 10.6).



▲ Figure 10.6 External and internal features of a leaf

Inside the leaf are layers of cells with different functions.

- The two outer layers of cells (the upper and lower **epidermis**) have few chloroplasts and are covered by a thin layer of a waxy material called the **cuticle**. This reduces water loss by evaporation, and acts as a barrier to the entry of disease-causing microorganisms such as bacteria and fungi.
- The lower epidermis has many holes or pores called **stomata** (a single pore is a **stoma**). Usually the upper epidermis contains fewer or no stomata. The stomata allow carbon dioxide to diffuse into the leaf, to reach the photosynthetic tissues. They also allow oxygen and water vapour to diffuse out. Each stoma is formed as a gap between two highly specialised cells called **guard cells**, which can change their shape to open or close the stoma.
- In the middle of the leaf are two layers of photosynthetic cells called the mesophyll ('mesophyll' just means 'middle of the leaf'). Just below the upper epidermis is the **palisade mesophyll** layer. This is a tissue made of long, narrow cells, each containing hundreds of chloroplasts, and is the main site of photosynthesis. The palisade cells are close to the source of light, and the upper epidermis is relatively transparent, allowing light to pass through to the enormous numbers of chloroplasts which lie below.
- Below the palisade layer is a tissue made of more rounded, loosely packed cells, with air spaces between them, called the **spongy mesophyll** layer. These cells also photosynthesise, but have fewer chloroplasts than the palisade cells. They form the main gas exchange surface of the leaf, absorbing carbon dioxide and releasing oxygen and water vapour. The air spaces allow these gases to diffuse in and out of the mesophyll.
- Water and mineral ions are supplied to the leaf by vessels in a tissue called the **xylem**. This forms a continuous transport system throughout the plant. Water is absorbed by the roots and passes up through the stem and through veins in the leaves in the **transpiration stream**. In the leaves, the water leaves the xylem and supplies the mesophyll cells.
- The products of photosynthesis, such as sugars, are carried away from the mesophyll cells by another transport system, the **phloem**. The phloem supplies all other parts of the plant, so that tissues and organs that can't make their own food receive products of photosynthesis. The veins in the leaf contain both xylem and phloem tissue, and branch again and again to supply all parts of the leaf.

You will find out more about both plant transport systems in Chapter 11.

KEY POINT

Starch is insoluble and so cannot be transported around the plant. The phloem carries only soluble substances such as sugars (mainly sucrose) and amino acids. These are converted into other compounds when they reach their destination.

FACTORS AFFECTING THE RATE OF PHOTOSYNTHESIS

When the light intensity rises, the rate of photosynthesis begins by rising too, but eventually it reaches a maximum rate. What makes the rate 'level off' (flatten) like this? It is because some other factor needed for photosynthesis is in short supply, so that increasing the light intensity does not affect the rate any more. Normally, the factor which 'holds back' the rate of photosynthesis is the concentration of carbon dioxide in the air. This is only about 0.03 to 0.04%, and the plant can only take up the carbon dioxide and fix it into carbohydrate at a certain rate. If the plant is put in a closed container with a higher than normal concentration of carbon dioxide, it will photosynthesise at a faster rate. If there is both a high light intensity and a high level of carbon dioxide, the temperature may limit the rate of photosynthesis, by limiting the rate of the chemical reactions in the leaf. A rise in temperature will then increase the rate. With normal levels of carbon dioxide, very low temperatures (close to 0 °C) slow the reactions, but high temperatures (above about 35 °C) also reduce photosynthesis by denaturing enzymes in the plant cells (see Chapter 1).

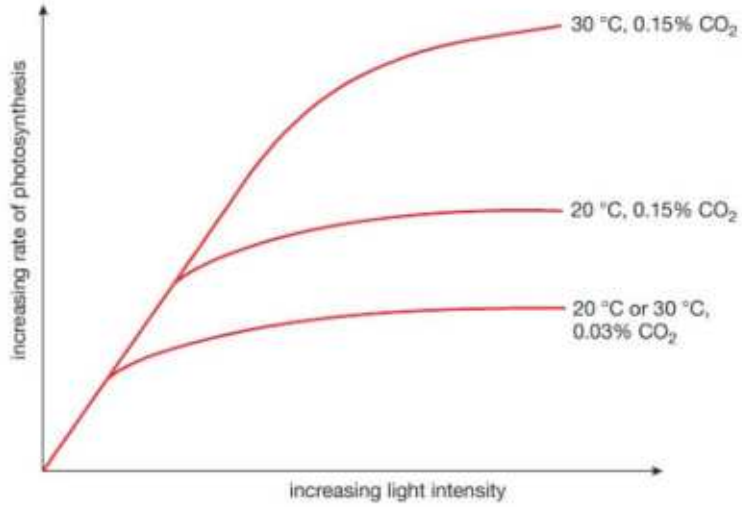
KEY POINT

A limiting factor is the component of a reaction that is in 'shortest supply' so that it prevents the rate of the reaction increasing, in other words sets a 'limit' to it.

KEY POINT

Knowledge of limiting factors is used in some glasshouses (greenhouses) to speed up the growth of crop plants such as tomatoes and lettuces (see Chapter 15). Extra carbon dioxide is added to the air around the plants, by using gas burners. The higher concentration of carbon dioxide, along with the high temperature in the glasshouse, increases the rate of photosynthesis and the growth of the leaves and fruits.

Light intensity, carbon dioxide concentration and temperature can all act as what are called **limiting factors** in this way. This is easier to see as a graph (Figure 10.7).



▲ Figure 10.7 Light intensity, carbon dioxide concentration and temperature can all act as limiting factors on the rate of photosynthesis.

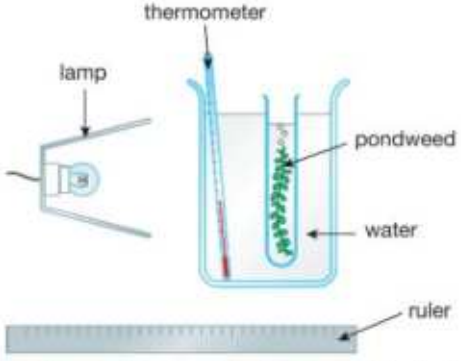
ACTIVITY 2

▼ PRACTICAL: MEASURING THE RATE OF PHOTOSYNTHESIS USING PONDWEED

Safety note: Wash hands after collecting and preparing pondweed. Do not handle the lamp, plug or switch with wet hands.

You can measure the rate of photosynthesis of a plant by measuring how quickly it produces oxygen. With a land plant this is difficult, because the oxygen is released into the air, but with an aquatic plant such as the pondweed *Elodea*, bubbles of oxygen are released into the water around the plant (Figure 10.5).

If the bubbles formed per minute are counted, this is a measure of the rate of photosynthesis of the plant. It is easiest to count the bubbles if the cut piece of weed is placed upside down in a test tube, as shown in Figure 10.8. A small paperclip attached to the bottom of the piece of weed makes it sink.



▲ Figure 10.8 Measuring the rate of photosynthesis in an aquatic plant.

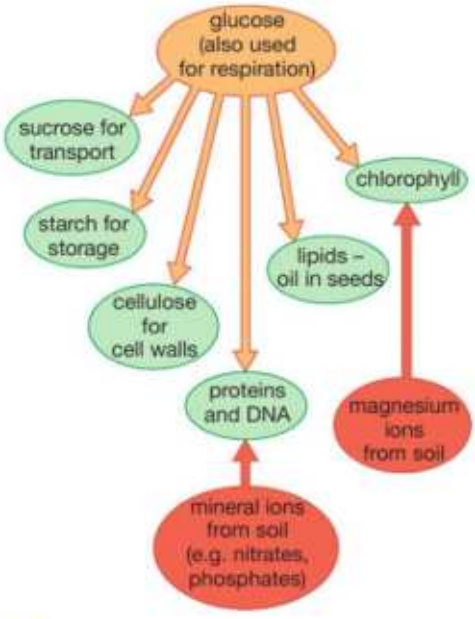
The light intensity is changed by moving the lamp, altering the distance between the lamp and the pondweed. The beaker of water keeps the temperature of the plant constant.

Design an experiment using this apparatus to find out if the rate of photosynthesis is affected by the light intensity. In your plan you should include:

- a hypothesis – state what you think will happen when you change the light intensity, and why
- a systematic way of changing the light intensity
- how the experiment will be controlled so that nothing else is changed apart from the light intensity (e.g. what will you do about the background light in the laboratory?)
- a Control that you could use, to show that it is the effect of light on the pondweed that is producing the bubbles
- how you will ensure that your results are reliable.

When you have completed your plan, you may be allowed to use similar apparatus to carry out the experiment. How could you modify your plan to find the effect of changing the *temperature* on the rate of photosynthesis? What factors would you need to keep constant this time? What would be a suitable range of temperatures to use?

THE PLANT'S USES FOR GLUCOSE



▲ Figure 10.9 Compounds that plant cells can make from glucose.

As you have seen, some glucose that the plant makes is used in respiration to provide the plant's cells with energy. Some glucose is quickly converted into starch for storage. However, a plant is not made up of just glucose and starch, and must make all of its organic molecules, starting from glucose.

Glucose is a single sugar unit (a **monosaccharide**). Plant cells can convert it into other sugars, such as a monosaccharide called **fructose** (found in fruits) and the disaccharide sucrose, which is the main sugar carried in the phloem. It can also be changed into another polymer, the polysaccharide called **cellulose**, which forms plant cell walls.

All these compounds are carbohydrates. Plant cells can also convert glucose into lipids (fats and oils). Lipids are needed for the membranes of all cells, and are also an energy store in many seeds and fruits, such as peanuts, sunflower seeds and olives.

Carbohydrates and lipids both contain only three elements – carbon, hydrogen and oxygen – and so they can be inter-converted without the need for a supply of other elements. Proteins contain these elements too, but all amino acids (the building blocks of proteins) also contain nitrogen. This is obtained as nitrate ions from the soil, through the plant's roots. Other compounds in plants contain other elements. For example, chlorophyll contains magnesium ions, which are also absorbed from water in the soil. Some of the products that a plant makes from glucose are summarised in Figure 10.9.

KEY POINT

Glucose from photosynthesis is not just used as the *raw material* for the production of molecules such as starch, cellulose, lipids and proteins. Reactions like these, which synthesise large molecules from smaller ones, also need a source of energy. This energy is provided by the plant's *respiration* of glucose.

MINERAL NUTRITION

Nitrate ions are absorbed from the soil water, along with other minerals such as phosphate, potassium and magnesium ions. The element phosphorus is needed for the plant cells to make many important compounds, including DNA. Potassium ions are required for enzymes in respiration and photosynthesis to work, and magnesium forms a part of the chlorophyll molecule.

WATER CULTURE EXPERIMENTS

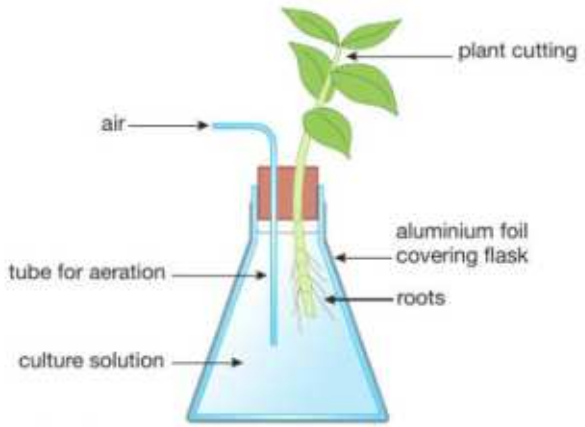
A plant takes only water and mineral ions from the soil for growth. Plants can be grown in soil-free cultures (water cultures) if the correct balance of minerals is added to the water. In the nineteenth century, the German biologist Wilhelm Knop invented one example of a culture solution. Knop's solution contains the following chemicals (per dm^3 of water):

0.8 g	calcium nitrate
0.2 g	magnesium sulfate
0.2 g	potassium nitrate
0.2 g	potassium dihydrogenphosphate
(trace)	iron(III) phosphate

DID YOU KNOW?

In fact, in addition to the ions listed in Knop's solution, plants need very small amounts of other mineral ions for healthy growth. Knop's culture solution only worked because the chemicals he used to make his solutions weren't very pure, and supplied enough of these additional ions by mistake!

Notice that these chemicals provide all of the main elements that the plant needs to make proteins, DNA and chlorophyll, as well as other compounds, from glucose. It is called a *complete* culture solution. If you were to make a similar solution, but to replace, for example, magnesium sulfate with more calcium sulfate, this would produce a culture solution which was *deficient* (lacking) in magnesium. You could then grow plants in the complete and deficient solutions, and compare the results. There are several ways to grow the plants, such as using the apparatus shown in Figure 10.10, which is useful for plant cuttings. Seedlings can be grown by packing cotton wool around the seed, instead of using a rubber bung.



▲ Figure 10.10 A simple water culture method

The plant is kept in bright light, so that it can photosynthesise. The covering around the flask prevents algae from growing in the culture solution. The aeration tube is used for short periods to supply the roots with oxygen for respiration of the root cells, since some ions are taken up by active transport. Using methods like this, it soon becomes clear that mineral deficiencies result in poor plant growth. A shortage of a particular mineral results in particular

symptoms in the plant, called a *mineral deficiency disease*. For example, lack of magnesium means that the plant won't be able to make chlorophyll, and the leaves will turn yellow. Lack of nitrate limits a plant's growth, because it is unable to make enough protein. Some of the mineral ions that a plant needs, their uses, and the deficiency symptoms are shown in Table 10.1. Compare the photographs of the mineral deficient plants to those of the control plant in Figure 10.11(a).



▲ Figure 10.11 (a) A healthy bean plant

Table 10.1: Mineral ions needed by plants

Mineral ion	Use	Deficiency symptoms
nitrate	making amino acids, proteins, chlorophyll, DNA and many other compounds	limited growth of plant; older leaves turn yellow  ▲ Figure 10.11 (b) A plant showing symptoms of nitrate deficiency.
phosphate	making DNA and many other compounds; part of cell membranes	poor root growth; younger leaves turn purple  ▲ Figure 10.11 (c) A plant showing symptoms of phosphate deficiency.
potassium	needed for enzymes of respiration and photosynthesis to work	leaves turn yellow with dead spots  ▲ Figure 10.11 (d) A plant showing symptoms of potassium deficiency.
magnesium	part of chlorophyll molecule	leaves turn yellow  ▲ Figure 10.11 (e) A plant showing symptoms of magnesium deficiency.

DID YOU KNOW?

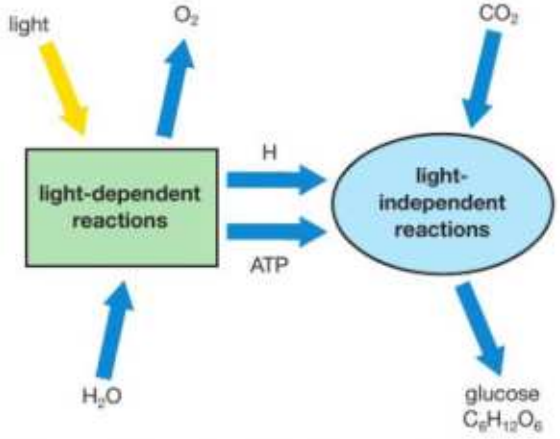
Some commercial crops such as lettuces can be grown without soil in culture solutions. This is called **hydroponics**. The plants' roots grow in a long plastic tube that has culture solution passing through it (Figure 10.12). The composition of the solution can be carefully adjusted to ensure the plants grow well. Pests such as insects, which might live in soil, are also less of a problem.



▲ Figure 10.12 Lettuce plants grown by hydroponics

LOOKING AHEAD – MORE ABOUT PHOTOSYNTHESIS

The role of chlorophyll is to absorb the light energy needed to drive photosynthesis. The products of the reaction (glucose and oxygen) contain more chemical energy than the reactants (carbon dioxide and water). The simple equation for photosynthesis that you saw earlier in this chapter is actually a summary of a series of reactions. They take place in two stages (Figure 10.13).



▲ Figure 10.13 Photosynthesis takes place in two stages called light-dependent and light-independent reactions.

The light energy absorbed by the chlorophyll is used to split water molecules into hydrogen and oxygen. The waste product, oxygen, is given off as a gas. At the same time, the light energy is used to convert ADP and phosphate into ATP. Because this stage needs light, the steps in the process are known as the *light-dependent reactions*.

Next, the hydrogen atoms from the water and energy from the ATP are used to reduce carbon dioxide to glucose. This takes place in another series of reactions in the chloroplast. Because these do not need light, they are called the *light-independent reactions*.

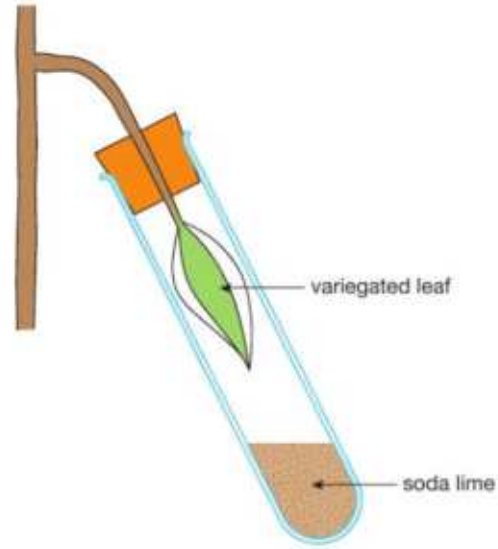
If you continue with biology beyond International GCSE, you will find out more about the biochemistry of photosynthesis.

CHAPTER QUESTIONS

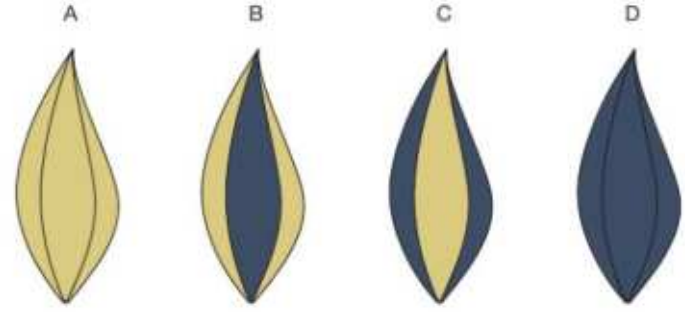
More questions on plants and food can be found at the end of Unit 3 on page 159.

SKILLS REASONING

1 A variegated leaf attached to a plant was placed in a test tube as shown below. The test tube contained soda lime to absorb carbon dioxide.



The plant was left in bright light for 24 hours and tested for starch using iodine solution. Which of the following diagrams shows the expected results?



SKILLS CRITICAL THINKING

2 Which of the following is not normally a factor that limits the rate of photosynthesis?

A temperature

B oxygen concentration

C carbon dioxide concentration

D light intensity

3 Which of the following compounds can only be made by a plant if it has access to magnesium ions?

A chlorophyll

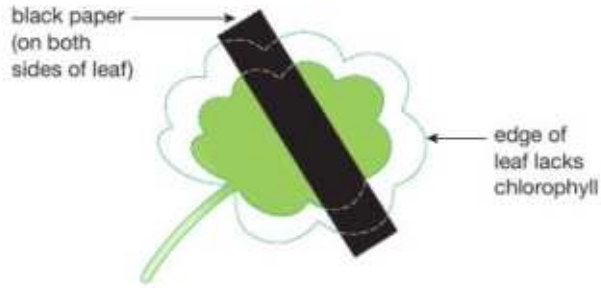
B cellulose

C starch

D protein

SKILLS CRITICAL THINKING

4 A plant with variegated leaves had a piece of black paper attached to one leaf as shown in the diagram.



The plant was kept under a bright light for 24 hours. The leaf was then removed, the paper taken off and the leaf was tested for starch.

a Name the chemical used to test for starch, and describe the colour change if the test is positive.

b Copy the leaf outline and shade in the areas which would contain starch.

c Explain how you arrived at your answer to (b).

SKILLS REASONING

d What is starch used for in a plant? How do the properties of starch make it suitable for this function?

SKILLS INTERPRETATION

5 Copy and complete the following table to show the functions of different parts of a leaf, and how that part is adapted for its function. One row has been done for you.

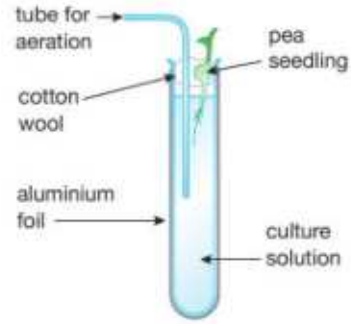
Part of leaf	Function	How the part is adapted for its function
palisade mesophyll layer	main site of photosynthesis	cells contain many chloroplasts for photosynthesis
spongy mesophyll layer		
stomata		
xylem		
phloem		

6 The table below shows some of the substances that can be made by plants. Give one use in the plant for each. The first has been done for you.

Substance	Use
glucose	oxidised in respiration to give energy
sucrose	
starch	
cellulose	
protein	
lipid	

SKILLS REASONING

7 The apparatus shown in the diagram was used to grow a pea seedling in a water culture experiment.

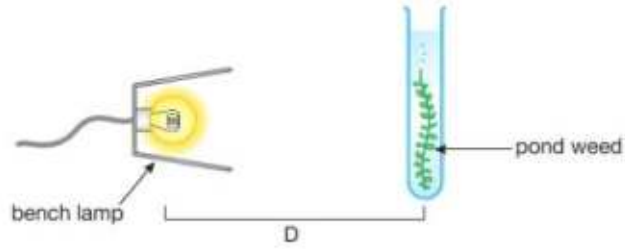


a Explain the purpose of the aeration tube and the aluminium foil around the test tube.

b After two weeks, the roots of the pea seedling had grown less than normal, although the leaves were well developed. What mineral ion is likely to be deficient in the culture solution?

SKILLS INTERPRETATION

8 A piece of Canadian pondweed was placed upside down in a test tube of water, as shown in the diagram.



Light from a bench lamp was shone onto the weed, and bubbles of gas appeared at the cut end of the stem. The distance of the lamp from the weed was changed, and the number of bubbles produced per minute was recorded. The results are shown in the table below.

Distance of lamp (D) / cm	Number of bubbles per minute
5	126
10	89
15	64
20	42
25	31
30	17
35	14
40	10

a Plot a graph of the number of bubbles per minute against the distance of the weed from the lamp.

SKILLS REASONING

b Using your graph, predict the number of bubbles per minute that would be produced if the lamp was placed 17 cm from the weed.

c The student who carried out this experiment arrived at the following conclusion:

'The gas made by the weed is oxygen from photosynthesis, so the faster production of bubbles shows that the rate of photosynthesis is greater at higher light intensities.'

Write down three reasons why his conclusion could be criticised. (Hint: is counting the bubbles a reliable method of measuring the rate of photosynthesis?)

SKILLS INTERPRETATION

9 Write a summary account of photosynthesis. You should include a description of the process, a summary equation, an account of how a leaf is adapted for photosynthesis and a note of how photosynthesis is important to other organisms, such as animals. You must keep your summary to less than two sides (about 500 words).

11 TRANSPORT IN PLANTS

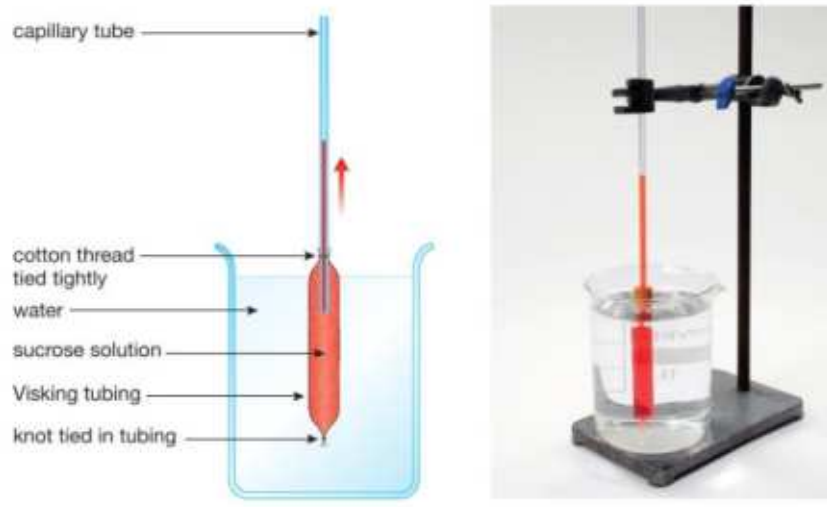
Chapter 10 described how plants make food by photosynthesis. Photosynthesis requires water from the roots to be transported to the leaves, and sugars and other products of photosynthesis to be transported away from the leaves to the rest of the plant. This chapter explains how these materials are moved through the plant.

LEARNING OBJECTIVES

- Understand how water can move in or out of plant cells by osmosis
- Investigate osmosis in living and non-living systems (plant cells and Visking tubing)
- Describe the role of the xylem in the transport of water and mineral ions from the roots to other parts of a plant
- Describe the role of phloem in the transport of sucrose and amino acids from the leaves to other parts of a plant
- Understand the origin of carbon dioxide and oxygen as waste products of metabolism and their loss from the stomata of a leaf

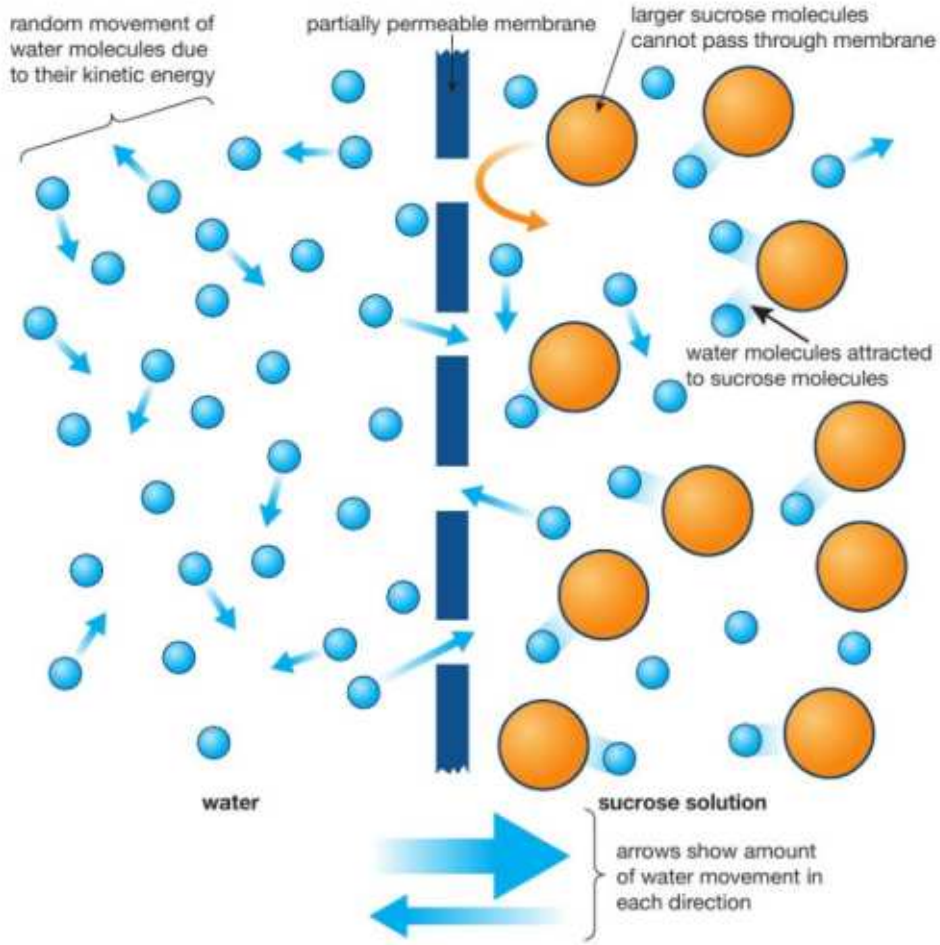
OSMOSIS

Osmosis is the name of a process by which water moves into and out of cells. In order to understand how water moves through a plant, you need to understand the mechanism of osmosis. Osmosis happens when a material called a **partially permeable membrane** separates two solutions. One artificial partially permeable membrane is called Visking tubing. This is used in kidney dialysis machines. Visking tubing has microscopic holes in it, which let small molecules like water pass through (it is *permeable* to them) but is not permeable to some larger molecules, such as the sugar sucrose. This is why it is called 'partially' permeable. You can show the effects of osmosis by filling a Visking tubing 'sausage' with concentrated sucrose solution, attaching it to a capillary tube and placing the Visking tubing in a beaker of water (Figure 11.1).



▲ Figure 11.1 Water enters the Visking tubing 'sausage' by osmosis. This causes the level of liquid in the capillary tube to rise. In the photograph, the contents of the Visking tubing have had a red dye added to make it easier to see the movement of the liquid.

The level in the capillary tube rises as water moves from the beaker to the inside of the Visking tubing. This movement is due to osmosis. You can understand what's happening if you imagine a highly magnified view of the Visking tubing separating the two liquids (Figure 11.2).



▲ Figure 11.2 In this model of osmosis, more water molecules diffuse from left to right than from right to left.

KEY POINT

Diffusion is the net movement of particles (molecules or ions) due to their kinetic energy, down a concentration gradient (see Chapter 1).

The sucrose molecules are too big to pass through the holes in the partially permeable membrane. The water molecules can pass through the membrane in either direction, but those on the right are attracted to the sugar molecules. This slows them down and means that they are less free to move – they have less kinetic energy. As a result of this, more water molecules diffuse from left to right than from right to left. In other words, there is a greater diffusion of water molecules from the more dilute solution (in this case pure water) to the more concentrated solution.

KEY POINT

It is important to realise that neither of the two solutions has to be pure water. As long as there is a difference in their concentrations (and their water potentials), and they are separated by a partially permeable membrane, osmosis can still take place.

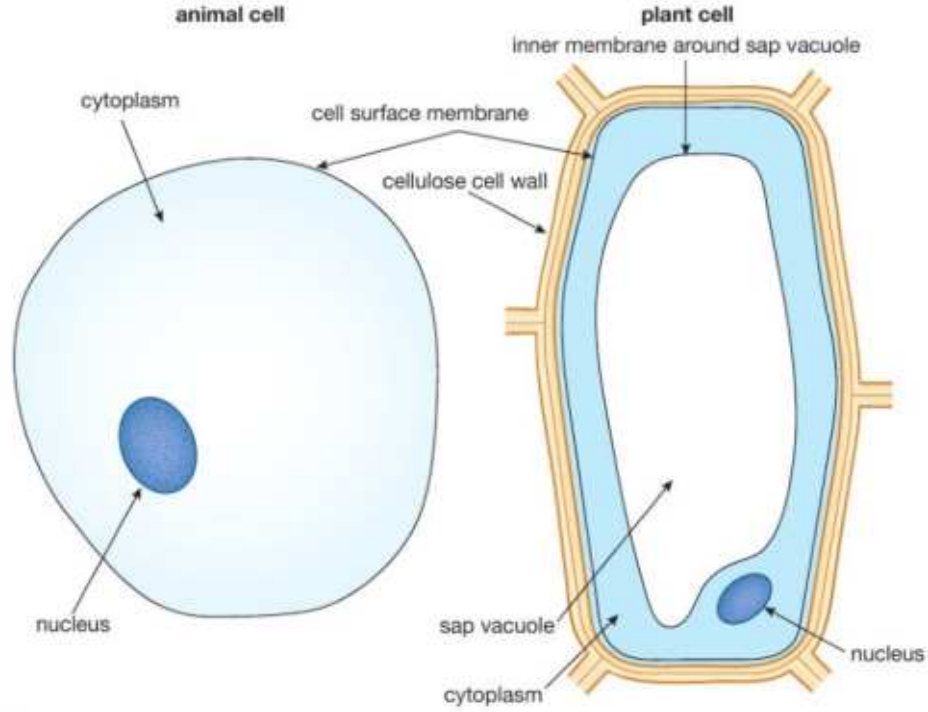
How 'free' the water molecules are to move is called the **water potential**. The molecules in pure water can move most freely, so pure water has the highest water potential. The more concentrated a solution is, the lower is its water potential. In the model in Figure 11.2, water moves from a high to a low water potential. This is a law which applies whenever water moves by osmosis. We can bring these ideas together in a definition of osmosis.

KEY POINT

Osmosis is the net diffusion of water across a partially permeable membrane, from a solution with a higher water potential to one with lower water potential.

OSMOSIS IN PLANT CELLS

So far we have only been dealing with osmosis through Visking tubing. However, there are partially permeable membranes in cells too. The cell surface membranes of both animal and plant cells are partially permeable, and so is the inner membrane around the plant cell's sap vacuole (Figure 11.3).



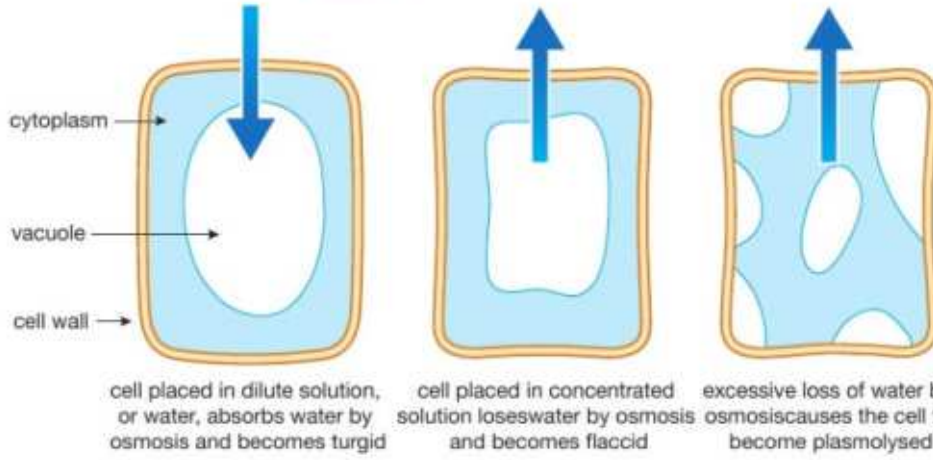
▲ Figure 11.3 Membranes in animal and plant cells

KEY POINT

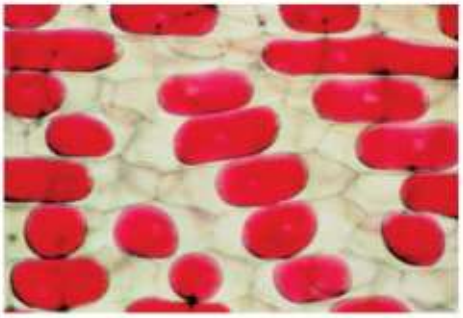
The cell *wall* has large holes in it, making it fully permeable to water and solutes. Only the cell *membranes* are partially permeable barriers that allow osmosis to take place.

Around the plant cell is the tough cellulose cell wall. This outer structure keeps the shape of the cell, and can resist changes in pressure inside the cell. This is very important, and critical in explaining the way that plants are supported. The cell contents, including the sap vacuole, contain many dissolved solutes, such as sugars and ions.

If a plant cell is put into pure water or a dilute solution, the contents of the cell have a lower water potential than the external solution, so the cell will absorb water by osmosis (Figure 11.4). The cell then swells up and the cytoplasm pushes against the cell wall. A plant cell that has developed an internal pressure like this is called **turgid**.



▲ Figure 11.4 The effects of osmosis on plant cells



▲ Figure 11.5 Cells of onion epidermis, showing plasmolysis. The cell membranes and cytoplasm can be seen to have pulled away from the cell wall.

On the other hand, if the cell is placed in a concentrated sucrose solution that has a lower water potential than the cell contents, it will *lose* water by osmosis. The cell decreases in volume and the cytoplasm no longer pushes against the cell wall. In this state, the cell is called **flaccid**. Eventually the cell contents shrink so much that the membrane and cytoplasm split away from the cell wall and gaps appear between the wall and the membrane. A cell like this is called **plasmolysed**. You can see plasmolysis happening in the plant cells shown in Figure 11.5. The space between the cell wall and the cell surface membrane will now be filled with the sucrose solution.

KEY POINT

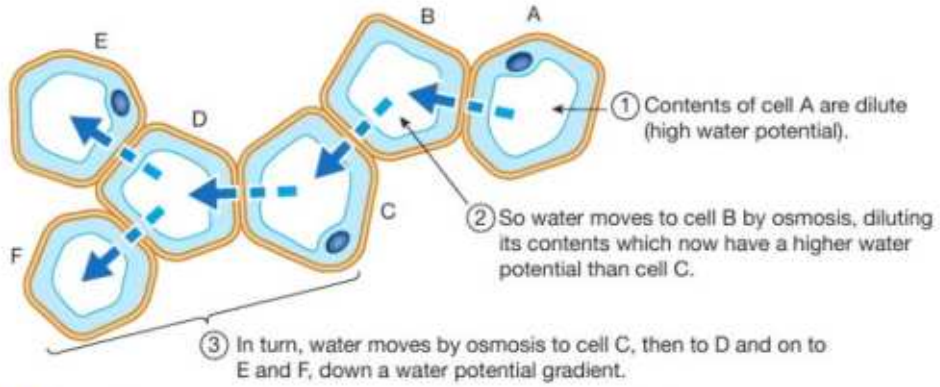
This chapter only covers plant cells. Osmosis also happens in animal cells, but there is much less water movement. This is because animal cells do not have a strong cell wall around them, and can't resist the changes in internal pressure resulting from large movements of water. For example, if red blood cells are put into water, they will swell up and burst. If the same cells are put into a concentrated salt solution, they lose water by osmosis and shrink, producing cells with crinkly edges (Figure 11.6).



◀ Figure 11.6 Compare the red blood cells on the right, which were placed in a 3% salt solution, with the normal cells on the left. Blood plasma has a concentration equal to a 0.85% salt solution.

Turgor (the state a plant is in when its cells are turgid) is very important to plants. The pressure inside the cells pushes neighbouring cells against each other, like a box full of inflated balloons. This supports the non-woody parts of the plant, such as young stems and leaves, and holds stems upright, so the leaves can carry out photosynthesis properly. Turgor is also important in the functioning of stomata. If a plant loses too much water from its cells so that they become flaccid, this makes the plant **wilt**. You can see wilting in a pot plant which has been left for too long without water. The leaves droop and collapse. In fact this is a protective action. It cuts down water loss by reducing the exposed surface area of the leaves and closing the stomata.

Inside the plant, water moves from cell to cell by osmosis. If a cell has a higher water potential than the cell next to it, water will move from the first cell to the second. In turn, this will dilute the contents of the second cell, so that it has a higher water potential than the next cell. In this way, water can move across a plant tissue, down a gradient of water potential (Figure 11.7).



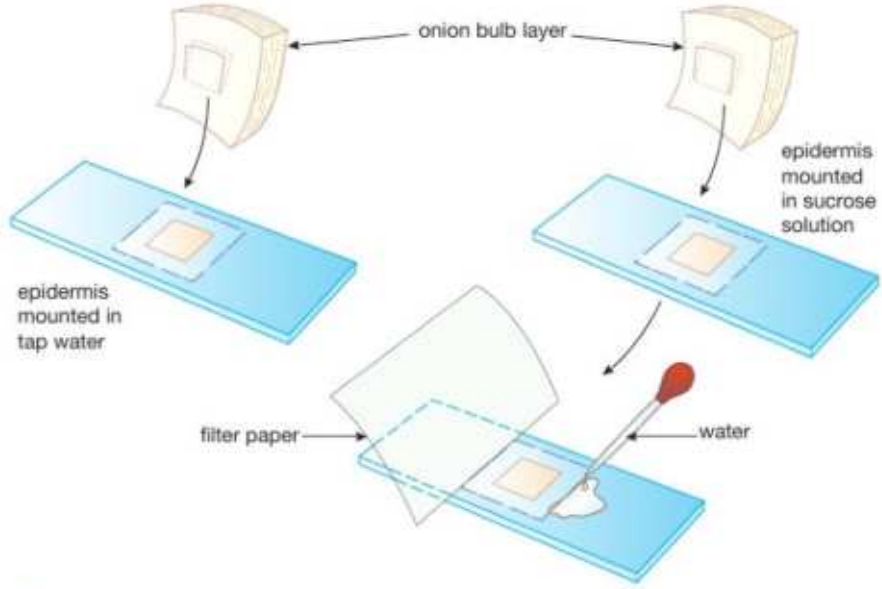
▲ Figure 11.7 Water moves from cell to cell down a water potential gradient.

Safety note: Wash hands after handling and preparing the onion. Microscopes using a mirror for daylight illumination must never be placed where direct sunlight might strike the mirror otherwise permanent retinal damage may occur.

ACTIVITY 3

▼ PRACTICAL: INVESTIGATING THE EFFECTS OF OSMOSIS IN ONION EPIDERMIS CELLS

A drop of concentrated (1 mol per dm^3) sucrose solution is placed on one microscope slide, and a drop of distilled water on a second slide. Two small squares of inner epidermis are removed from the outer fleshy layers of an onion (Figure 11.8). One square is transferred to the sucrose solution, and the second to the water. This is done as quickly as possible, so that the cells do not dry out.



▲ Figure 11.8 Investigating osmosis in onion epidermis cells

A drop of the correct solution is added to the top of each specimen, followed by a cover slip. Any excess liquid is blotted (cleaned) up with filter paper.

Each slide is examined through the microscope for several minutes. The specimen in water will show turgid cells, similar to the first cell in Figure 11.4. The cells in sucrose solution will gradually plasmolyse, as shown in the last diagram of Figure 11.4, and Figure 11.5.

It is interesting to replace the sugar solution on the first slide with distilled water, to see the effect on the plasmolysed cells. This can be done quite easily without removing the cover slip. Some water is placed on one side of the cover slip and drawn across the slide using filter paper, as shown in Figure 11.8. After a while all the sucrose solution is replaced by water. If the cells are now observed for a few minutes, they will gradually recover from their plasmolysed condition until they are fully turgid again.

It may be possible for you to carry out these procedures. If you can, observe and draw one or two turgid cells, and one or two that are plasmolysed.

Can you explain all these observations in terms of osmosis?

If you use a red onion, the contents of the cells are coloured and easier to see.

Safety note: Take great care when cutting the potato into 'chips' and wash hands afterwards.

ACTIVITY 4

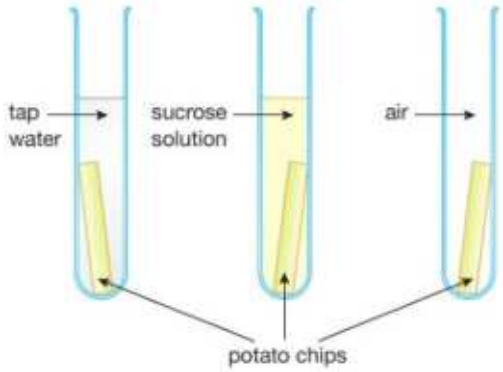
▼ PRACTICAL: INVESTIGATING THE EFFECTS OF OSMOSIS ON POTATO TUBER TISSUE

A potato tuber is a plant storage organ. It is a convenient tissue to use to investigate the effects of osmosis on the mass of the tissue.

A boiling tube is half filled with distilled water and a second with concentrated (1 mol per dm^3) sucrose solution. A third tube is left empty.

A potato is cut into chips 5 cm × 1 cm × 1 cm, making these measurements as accurate as possible so that the three chips are the same size. No skin is left on the potato tissue.

Each chip is gently blotted to remove excess moisture, and the mass of each is found by weighing on a balance. One chip is placed in each of the three boiling tubes (Figure 11.9).



▲ Figure 11.9 Investigating osmosis in potato tissue

After 30 minutes, the chips are removed from the tubes and gently blotted to remove excess liquid, then re-weighed. Each is felt in turn, to compare how flexible or stiff they are.

The change in mass (+ or –) of each chip is calculated, and the percentage change found from the equation:

$$\% \text{ change} = \frac{\text{change in mass}}{\text{starting mass}} \times 100$$

The table below shows a set of results from this experiment.

Tube contents	Starting mass / g	Final mass / g	Change in mass / g	Change in mass / %	Condition (flexible / stiff)
water	6.25	6.76	+0.51	+8.16	stiff
sucrose solution	7.10	6.31	–0.79	–11.1	flexible
air	6.66	6.57	–0.09	–1.35	stiff

What conclusions can you make from these results? Explain them in terms of osmosis.

How large are the percentage changes in mass of the chips in the two liquids, compared with the chip in air?

Can you explain the final 'condition' of the chips, using terms such as 'flaccid' and 'turgid'?

Can you think of any criticisms of this experiment? For example, does using one chip per tube yield reliable evidence?

You may be able to perform an experiment similar to the one above. You don't have to use potato; other tissues such as carrot or sweet potato should work. An alternative to weighing is to measure the length of the chips at the end of the experiment, and compare these measurements with the starting lengths. However, weighing is much more accurate and gives a bigger percentage change.

You could try extending the experiment into a more complete investigation. For example you could make predictions about what would happen to chips placed in solutions that are intermediate in concentration between water and molar sucrose solution.

Plan a method to test your hypothesis. You should include a list of the apparatus and materials to be used, a description of the procedure, and a statement of the expected results.

TRANSPORT IN THE XYLEM

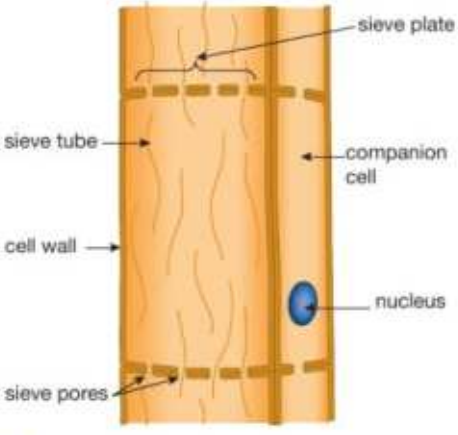


▲ Figure 11.10 Xylem vessels in a stem. The spirals and rings (stained red) are made of lignin.

Xylem transports water and minerals throughout the plant. Xylem contains dead cells arranged end-to-end, forming continuous vessels. When they are mature, the vessels contain no cytoplasm. Instead, they have a hollow central space or **lumen** through which the water passes. The walls of the xylem vessels contain a woody material called **lignin** (Figure 11.10).

The xylem vessels begin life as living cells with normal cytoplasm and cellulose cell walls. As they develop they become elongated, and gradually their original cellulose cell walls become impregnated with lignin, made by the cytoplasm. As this happens, the cells die, forming hollow tubes. Lignification makes them very strong, and enables them to carry water up tall plants without collapsing. Lignin is also impermeable to water.

TRANSPORT IN THE PHLOEM



▲ Figure 11.11 Xylem vessels in a stem

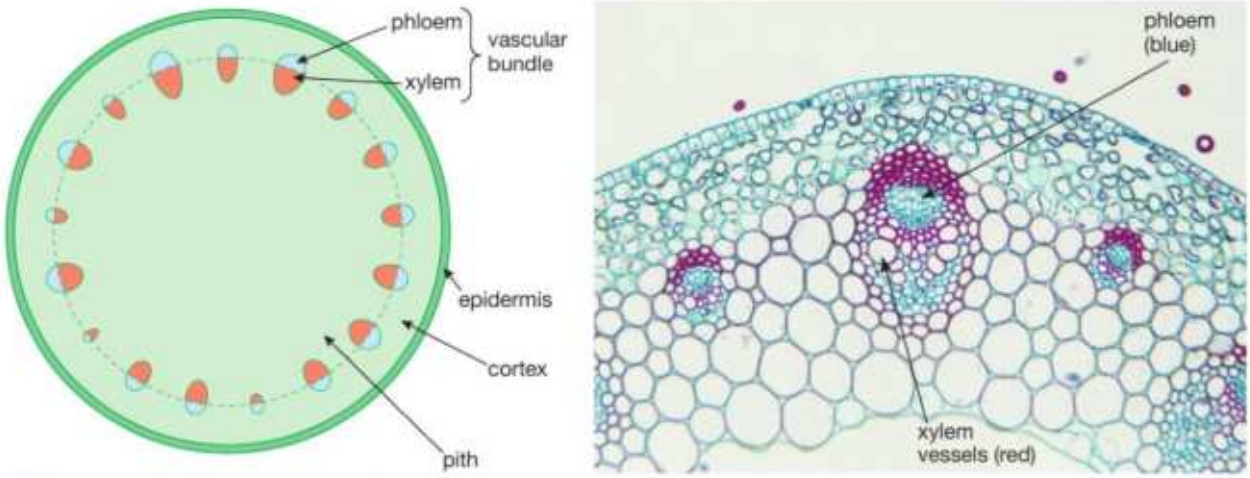
The other plant transport tissue, the phloem, consists of living cells at all stages in its development. Tubes in the phloem are also formed by cells arranged end-to-end, but they have cell walls made of cellulose, and retain their cytoplasm. The end of each cell is formed by a cross-wall of cellulose with holes, called a **sieve plate**. The living cytoplasm extends through the holes in the sieve plates, linking each cell with the next, forming a long **sieve tube** (Figure 11.11). The sieve tubes transport the products of photosynthesis from the leaves to other parts of the plant. Sugars for energy, or amino acids for building proteins, are carried to young leaves and other growing points in the plant. Sugar may also be taken to the roots and converted into starch for storage. Despite being living cells, the phloem sieve tubes have no nucleus. They seem to be controlled by other cells that lie alongside the sieve tubes, called **companion cells** (Figure 11.11).

REMINDER

Remember: xylem carries water and minerals up from the roots. Phloem carries products of photosynthesis away from the leaves. The contents of the phloem can travel up or down the plant.

STRUCTURE OF A STEM

In a young stem, xylem and phloem are grouped together in areas called **vascular bundles**. Unlike in the root, where the vascular tissue is in the central core, the vascular bundles are arranged in a circle around the outer part of the stem (Figure 11.12).



▲ Figure 11.12 (a) This cross-section of a stem shows the arrangement of xylem and phloem tissue in vascular bundles. (b) Three vascular bundles in part of a stem section. The outer red cells are lignified fibres for extra support.

KEY POINT

'Vascular' means 'made of vessels'. A vascular bundle is a group of vessels or tubes (xylem and phloem).

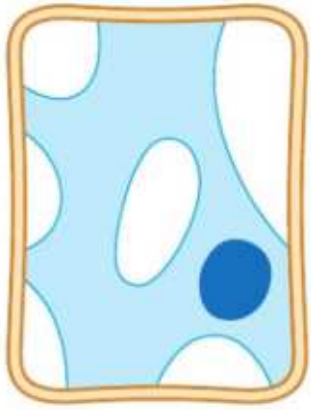
In older stems, the vascular tissue grows to form complete rings around the stem. The inner xylem forms the woody central core of a stem, with the living layer of phloem outside this.

CHAPTER QUESTIONS

More questions on transport in plants can be found at the end of Unit 3 on page 159.

SKILLS CRITICAL THINKING

1 A plant cell was placed in a concentrated sucrose solution. The diagram below shows the appearance of the cell after an hour in the solution.



What is the best description of this cell?

A turgid

B flaccid

C plasmolysed

D wilted

SKILLS CRITICAL THINKING

2 What are the functions of xylem and phloem?

A xylem transports water and sugars, phloem transports mineral ions

B xylem transports water and mineral ions, phloem transports sugars

C xylem transports sugars and mineral ions, phloem transports water

D xylem transports sugars, phloem transports water and mineral ions

SKILLS PROBLEM SOLVING

3 Three 'chips' of about the same size and shape were cut from the same potato. Each was blotted, weighed and placed in a different sucrose solution (A, B or C). The chips were left in the solutions for an hour, then removed, blotted and re-weighed. Here are the results:

	Starting mass / g	Final mass / g	Change in mass / %
solution A	7.4	6.5	−12.2
solution B	8.2	8.0	
solution C	7.7	8.5	+10.4

a Calculate the percentage change in mass for the chip in solution B.

SKILLS CRITICAL THINKING

b Name the process that caused the chips to lose or gain mass.

SKILLS ANALYSIS

c Which solution was likely to have been the most concentrated?

d Which solution had the highest water potential?

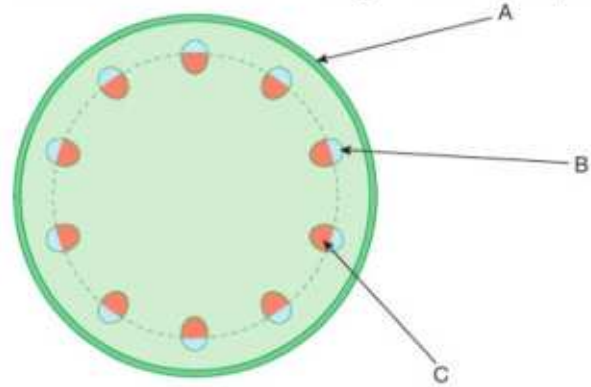
e Which solution had a water potential most similar to the water potential of the potato cells?

SKILLS CRITICAL THINKING

f The cell membrane is described as 'partially permeable'. Explain the meaning of this.

SKILLS ANALYSIS

4 The diagram shows a cross-section through the stem of a plant.



a Identify the tissues labelled A, B and C.

SKILLS REASONING

b A young stem was placed in a solution of a red dye for an hour. Which tissue in the diagram would be most likely to contain the dye? Explain your answer.

12 CHEMICAL COORDINATION IN PLANTS

Plants can detect changes in their environment and respond to them, but the responses are much slower than those in animals. This is because movements in a plant are brought about by changes in the plant's growth. This chapter is about these growth responses, and the chemicals that coordinate them.

LEARNING OBJECTIVES

- Understand that plants respond to stimuli
- Describe the phototropic response of roots and stems
- Describe the geotropic responses of roots and stems
- Understand the role of auxin in the phototropic response of stems

Chapter 6 explains how animals detect and respond to changes in their environment. Animals usually respond very quickly – for example the reflex action resulting from a painful stimulus (page 83) is over in a fraction of a second.

As in animals, some species of plant can respond rapidly to a stimulus, for example the Venus flytrap (Figure 12.1). This plant has modified leaves, which close quickly around their 'prey', trapping it. The plant then secretes enzymes to digest the insect. The movement is brought about by rapid changes in turgor of specialised cells at the base of the leaves.



▲ Figure 12.1 The Venus flytrap catches and digests insects to gain extra nutrients. The plant responds very quickly to a fly landing on one of its leaves.



▲ Figure 12.2 This bean has responded to being placed horizontally. The growing shoot has started to bend upwards.

TROPISMS

Most plants do not respond to stimuli as quickly as the Venus flytrap, because their response normally involves a change in their rate of growth. Different parts of plants may grow at different rates, and a plant may respond to a stimulus by increasing growth near the tip of its shoot or roots.

Imagine a plant growing normally in a pot. Usually, most light will be falling on the plant from above. If you turn the plant on its side and leave it for a day or so, you will see that its shoot starts to grow upwards (Figure 12.2).



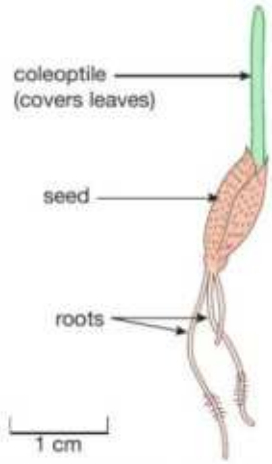
▲ Figure 12.3 The shoots of these tomato seedlings are showing a positive phototropism.

KEY POINT

Phototropisms are growth responses to light from one direction. Geotropisms are growth responses to the direction of gravity ('geo' refers to the Earth).

KEY POINT

Light from one direction is called 'unidirectional'. If light shines on the plant evenly from all directions, this is called 'uniform' light.



▲ Figure 12.4 Germinating oat seedling

EXTENSION WORK

Charles Darwin is best known for his theory of evolution by natural selection (Chapter 19). However, he carried out research in other areas of biology, including studying plant hormones. You could do some research to find out more about his life and work. Make a list of his achievements.

There are two stimuli acting on the plant in Figure 12.2. One is the direction of the light that falls on the plant. The other stimulus is gravity. Both light and gravity are *directional* stimuli (they act in a particular direction). The growth response of a plant to a directional stimulus is called a **tropism**. If the growth response is *towards* the direction of the stimulus, it is a *positive* tropism, and if it is *away* from the direction of the stimulus, it is a *negative* tropism. The stem of the plant in Figure 12.2 is showing a positive **phototropism** and a negative **geotropism**, which both make the stem grow upwards.

The aerial part of a plant (the 'shoot') needs light to carry out photosynthesis. This means that in most species, a positive phototropism is the strongest tropic response of the shoot. If a shoot grows towards the light, it ensures that the leaves, held out at an angle to the stem, will receive the maximum amount of sunlight. This response is easily seen in any plant placed near a window, or another source of 'one-way' or *unidirectional* light (Figure 12.3).

In darkness or uniform light, the shoot shows a negative geotropism. As you might expect, the roots of plants are strongly positively geotropic. This response makes sure that the roots grow down into the soil, where they can reach water and mineral ions. Roots also fix a plant firmly in place – they provide 'anchorage'.

The roots of some species that have been studied are also negatively phototropic, but most roots don't respond to directional light at all. Table 12.1 summarises the main tropisms.

Table 12.1: The main responses of plants to directional stimuli (tropisms).

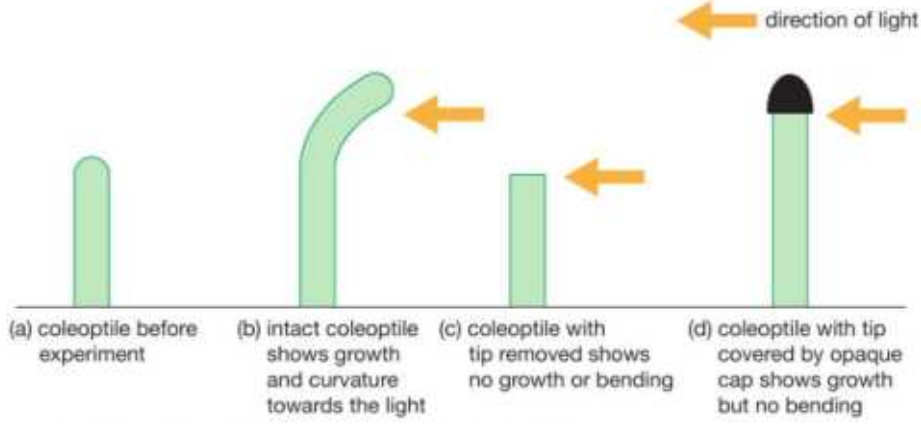
Stimulus	Name of response	Response of shoots	Response of roots
light	phototropism	grow towards light source (positive phototropism)	most species show no response; some grow away from light (negative phototropism)
gravity	geotropism	grow away from direction of gravity (negative geotropism)	grow towards direction of gravity (positive geotropism)

DETECTING THE LIGHT STIMULUS – PLANT HORMONES

Plants do not have the obvious sense organs and nervous system of animals. However, since they respond to stimuli such as light and gravity, they must have some way of detecting them and coordinating the response. The detection system of phototropism was first investigated by the great English biologist Charles Darwin (see Chapter 19) in the late nineteenth century. Instead of using stems, Darwin (and later scientists) used cereal coleoptiles, which are easier to grow and use in experiments.

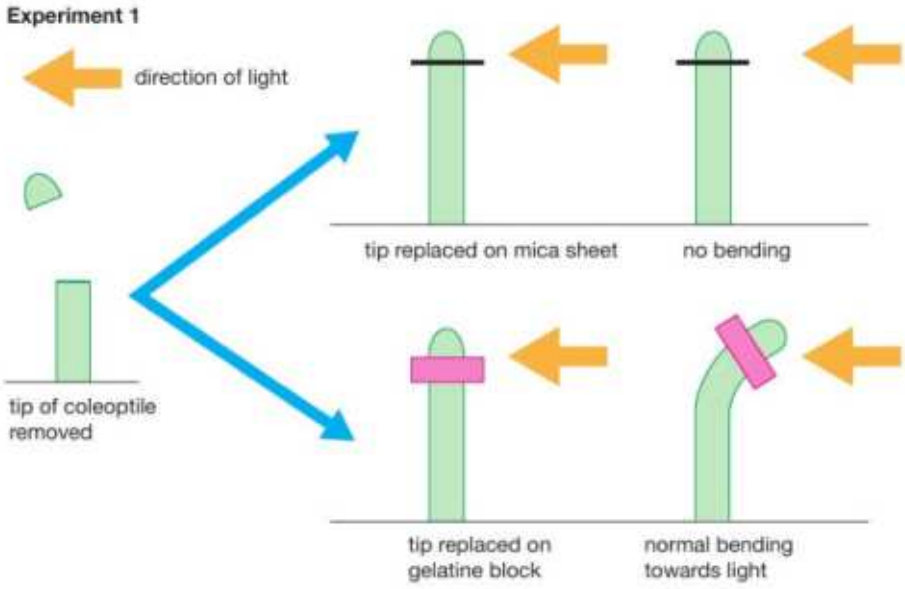
A **coleoptile** is a protective sheath that covers the first leaves of a cereal seedling. It protects the delicate leaves as the shoot emerges through the soil (Figure 12.4). Coleoptiles have a simple structure and are easy to grow, so they are often used to investigate tropisms.

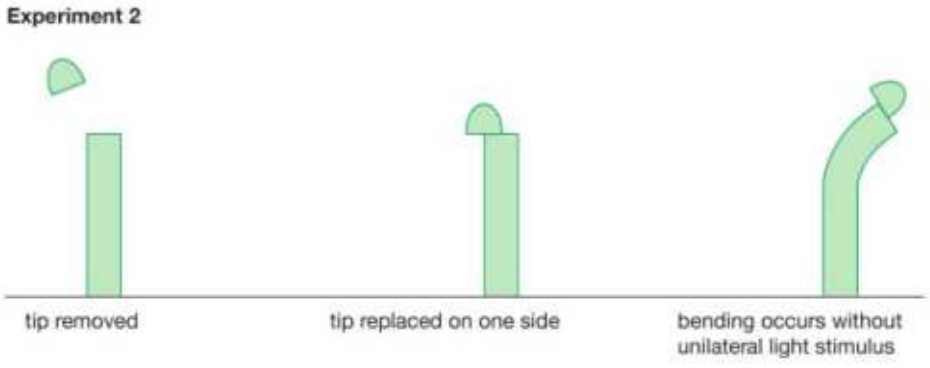
Darwin showed that the stimulus of unidirectional light was detected by the tip of the coleoptile, and transmitted to a growth zone, just behind the tip (Figure 12.5).

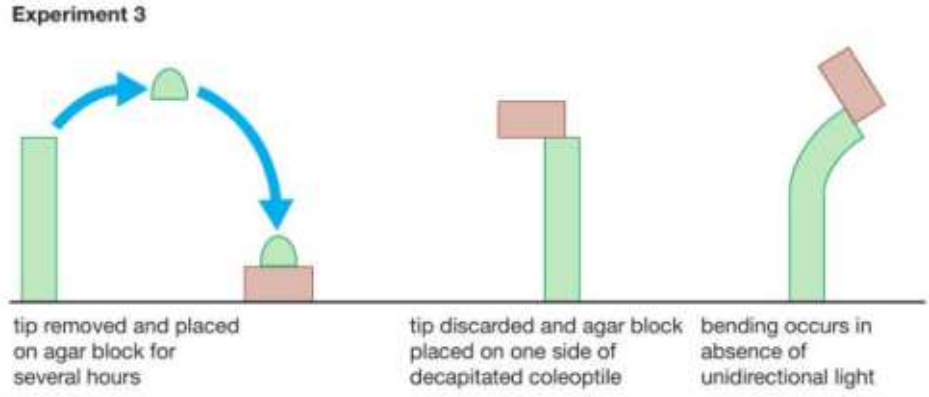


▲ Figure 12.5 Darwin's experiments with phototropism (1880)

Since plants don't have a nervous system, biologists began to look for a chemical messenger (or plant **hormone**) that might be the cause of phototropism in coleoptiles. Between 1910 and 1926 several scientists investigated this problem. Some of their results are summarised in Figure 12.6.







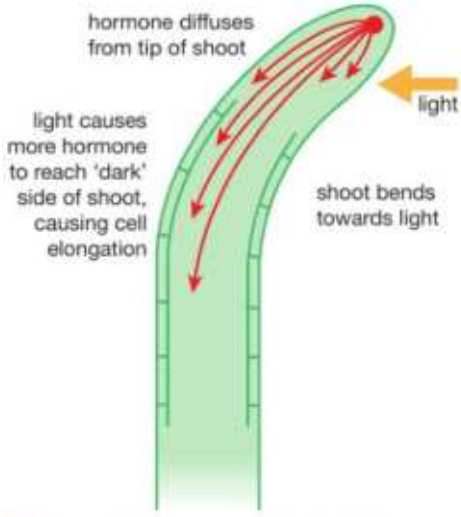
▲ Figure 12.6 Experiments on coleoptiles that helped to explain the mechanism of phototropism.

In experiment 1, the stimulus for growth was found to pass through materials such as gelatine, which absorbs water-soluble chemicals, but not through materials such as mica (a mineral), which is impermeable to water. This made biologists think that the stimulus was a chemical that was soluble in water.

In experiment 2, it was shown that the phototropic response could be brought about, even *without* unidirectional light, by removing a coleoptile tip ('decapitating' the coleoptile) and placing the tip on one side of the decapitated stalk.

In experiment 3, it was found that the hormone could be collected in another water-absorbing material (a block of agar jelly). Placing the agar block on one side of the decapitated coleoptile stalk caused it to bend.

Investigations like experiments 2 and 3 led scientists to believe that the hormone caused bending by stimulating growth on the side of the coleoptile furthest from the light. The theory is that the hormone is produced in the tip of the shoot, and diffuses back down the shoot. If the shoot is in the dark, or if light is all around the shoot, the hormone diffuses at equal rates on each side of the shoot, so it stimulates the shoot equally on all sides. However, if the shoot is receiving light from one direction, the hormone moves away from the light as it diffuses downwards. The higher concentration of hormone on the 'dark' side of the shoot stimulates cells there to grow, making the shoot bend towards the light (Figure 12.7).



▲ Figure 12.7 How movement of a plant hormone causes phototropism.

Since these experiments were carried out, scientists have identified the hormone responsible. It is called **auxin**. Several other types of plant hormone have been found. Like auxin, they all influence growth and development of plants in one way or another, so that many scientists prefer to call them **plant growth substances** rather than plant hormones.

EXTENSION WORK

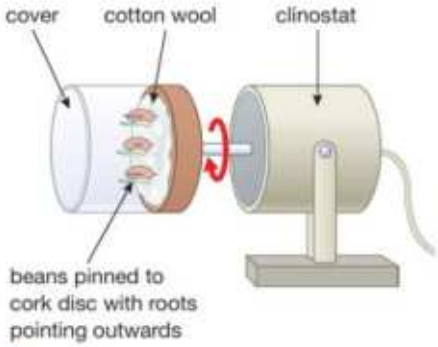
'Auxin' should really be 'auxins', since there are a number of chemicals with very similar structures making up a group of closely related plant hormones.

EXTENSION WORK

As well as auxins, there are four other main groups of plant hormones, called gibberellins, cytokinins, abscisic acid and ethene. They control many aspects of plant growth and development, apart from tropisms. These include growth of buds, leaves and fruit, fruit ripening, seed germination, leaf fall and opening of stomata, to name just a few.

USING A CLINOSTAT TO SHOW TROPISMS

A clinostat is a piece of apparatus consisting of an electric motor turning a cork disc. Germinating seeds are attached to the disc. The motor turns the disc and seeds around very slowly, so that the movement eliminates the effect of any directional stimulus that may be acting on the seeds. The clinostat can be turned through 90°, so that the disc rotates either horizontally or vertically.



▲ Figure 12.8 A clinostat

The clinostat can be used to demonstrate tropisms, for example geotropism in roots. A few beans are soaked in water overnight and then placed on wet cotton wool for a day or two, until the first root of each seed (called the radicle) grows to a length of about 2 cm.

Wet cotton wool is attached to the cork disc of two clinostats. Three or four of the germinating bean seeds are pinned on to each of the discs, with their radicles pointing outwards. Covers are placed over them to keep the air around the beans moist.

The clinostats are turned on their sides, as shown in Figure 12.8. One clinostat is switched on, with the other left switched off, as a control. Both clinostats are left set up for a few days. The cotton wool is watered regularly to keep it damp.

After this time, the radicles of the beans on the control clinostat will have grown downwards, under the influence of gravity. Those on the moving clinostat will have grown straight out horizontally. The continuously changing direction of the gravitational stimulus acting on the seeds of the moving clinostat cancels out the geotropic response.

CHAPTER QUESTIONS

More questions on chemical coordination in plants can be found at the end of Unit 3 on page 159.

SKILLS CRITICAL THINKING

1 Which of the following statements about tropisms is correct?

A Roots show positive phototropism and negative geotropism
B Roots show negative phototropism and positive geotropism
C Stems show negative phototropism and negative geotropism
D Stems show positive phototropism and positive geotropism

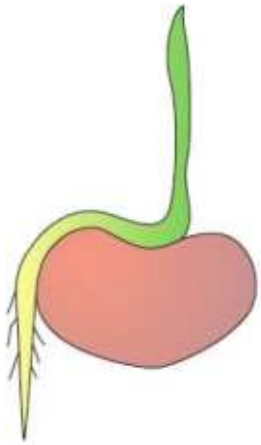
2 Below are three statements about phototropism in a coleoptile.

1. Auxin is made in the tip of the coleoptile
2. Auxin diffuses towards the light
3. A high concentration of auxin stimulates growth of the coleoptile towards the light.

Which of these statements are true?

A 1 and 2
B 1 and 3
C 2 and 3
D 1, 2 and 3

3 The diagram below shows a bean seedling that has been growing in the dark.



What is the name given to the response of the shoot?

A positive phototropism
B negative phototropism
C positive geotropism
D negative geotropism

SKILLS CRITICAL THINKING

4 Movement of auxin is thought to take place by which of the following methods?

A diffusion
B active transport
C osmosis
D mass flow in the phloem

5 a What are the main stimuli affecting the growth of
i the shoot? ii the root?

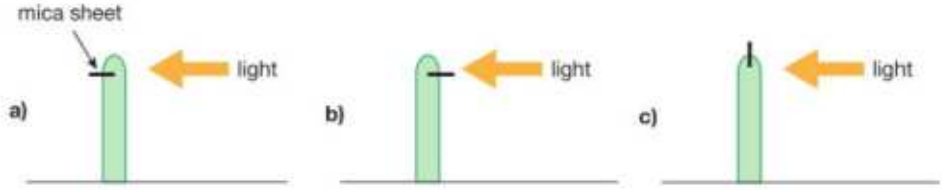
b How does a plant benefit from a positive phototropism in its stem?

SKILLS INTERPRETATION

6 Draw a labelled diagram to show how auxin brings about phototropism in a coleoptile that has light shining on it from one direction.

SKILLS REASONING

7 An experiment was carried out to investigate phototropism in a coleoptile. The diagram shows what was done. Predict the results you would expect to get in each of the experiments a) to c). Explain your answers.

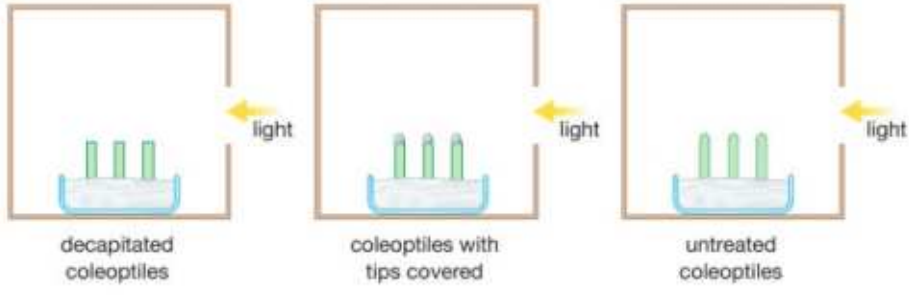


SKILLS EXECUTIVE FUNCTION

8 An experiment was carried out to investigate which part of a coleoptile is sensitive to a light stimulus. Three dishes containing wheat seedlings were subjected to different treatments:

- Dish 1 – 2 mm was removed from the growing coleoptiles ('decapitated' coleoptiles)
- Dish 2 – the tips of the coleoptiles were covered with caps of aluminium foil
- Dish 3 – the seedlings were left untreated as a control.

The coleoptiles were measured and the mean length of each treatment group was calculated. Each batch of seedlings was then placed in a box with a hole cut in one side to provide a unidirectional source of light.



After 48 hours the new mean length of the coleoptiles was found for each treatment group, and the percentage increase in length calculated. Any change in direction of growth of the coleoptiles was noted.

a Suggest which treatment would produce the greatest percentage increase in length and which the least. Explain your answer.

SKILLS REASONING

b What differences in direction of growth would you expect to see as a result of the three treatments? Explain your answer.

c Explain why it is necessary to calculate the *percentage* increase in the length of the coleoptiles, rather than simply the increase in length.

13 REPRODUCTION IN PLANTS

Plants, like animals, can reproduce sexually and asexually. The sexual organs of a flowering plant are its flowers, which produce pollen and ovules containing the flower's gametes. This chapter looks at both types of reproduction in flowering plants.

LEARNING OBJECTIVES

- Describe the differences between sexual and asexual reproduction in plants
- Understand that plants can reproduce asexually by natural methods (illustrated by runners) and by artificial methods (illustrated by cuttings)
- Describe the structures of an insect-pollinated and a wind-pollinated flower and explain how each is adapted for pollination
- Understand that the growth of the pollen tube followed by fertilisation leads to seed and fruit formation
- Understand how germinating seeds utilise food reserves until the seedling can carry out photosynthesis
- Investigate the conditions needed for seed germination

SEXUAL AND ASEXUAL REPRODUCTION

You have seen how animals can reproduce sexually and asexually (Chapter 9). Plants can also carry out both types of reproduction. Table 13.1 summarises some of the differences between the two methods of reproduction.

Table 13.1 Sexual and asexual reproduction compared.

Feature of the process	Sexual reproduction	Asexual reproduction
gametes produced	yes	no
fertilisation takes place	yes	no
genetic variation in offspring	yes	no
has survival value in:	changing environment	stable environment

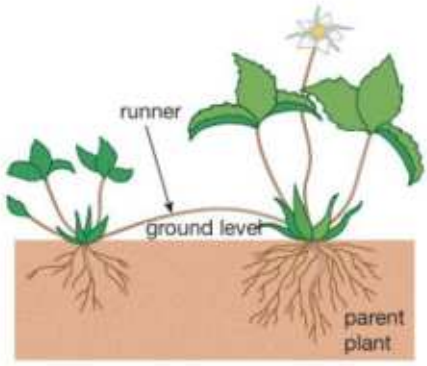
KEY POINT

As each method of asexual reproduction involves some part of the plant growing, new cells must be produced. These cells are produced by **mitosis** and so are all genetically identical. This means that all the offspring formed by asexual reproduction will also be genetically identical.

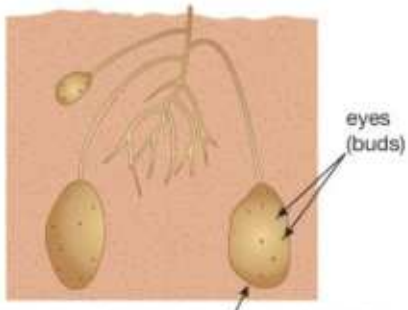
ASEXUAL REPRODUCTION IN PLANTS

There are many different methods of asexual reproduction in plants. Most involve some part of the plant growing, and then breaking away from the parent plant before developing into a new plant (Figure 13.1).

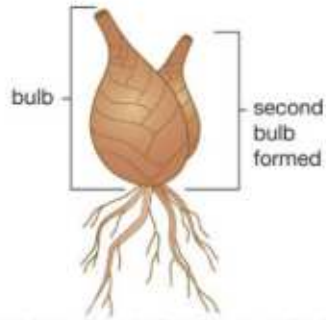
Gardeners often take advantage of the ways that plants can reproduce asexually. They use runners, bulbs and tubers to produce more plants.



A new plant is produced where the runner touches the ground.



Potato tubers form underground at the ends of branches from the main stem. Each potato can produce several new plants from the 'eyes' which are buds.



Some plants form bulbs. They are the bases of leaves which have become swollen with food. Buds in them can develop into new plants. Plants can form more than one bulb.

▲ Figure 13.1 Some methods of asexual reproduction in plants

Another type of asexual reproduction is to grow plants from **cuttings**. A piece of a plant's stem, with a few leaves attached, is cut from a healthy plant. This is planted in damp soil or compost, where it will grow roots and develop into a new plant (Figure 13.2).



▲ Figure 13.2 These geranium cuttings have started to grow roots

SEXUAL REPRODUCTION IN PLANTS

REMINDER

Haploid cells have only half the number of chromosomes of other body cells of that species.

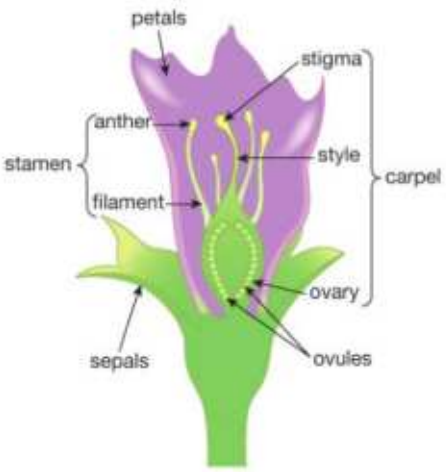
Plants produce specialised, haploid gametes in their flowers. The male gametes are contained within the **pollen grains** and the female gametes are egg cells or **ova**. Just as in animals, the male gametes must be transferred to the female gametes. This takes place through **pollination**, which is normally carried out either by wind or insects. Following pollination, fertilisation takes place and the zygote formed develops into a **seed**, which, in turn, becomes enclosed in a **fruit**.

PRODUCTION OF GAMETES AND POLLINATION

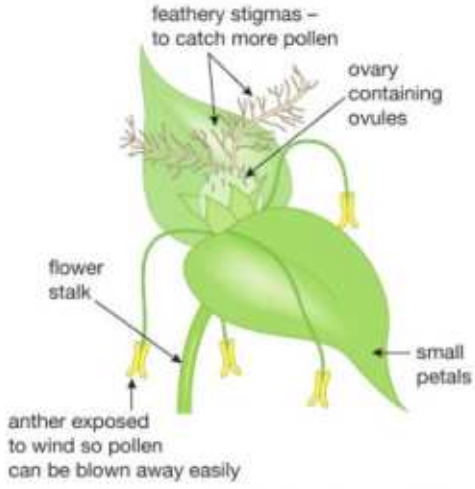
The gametes are produced by meiosis in structures in the flowers. Pollen grains are produced in the **anthers** of the **stamens**. The ova are produced in **ovules** in the **ovaries**.

In pollination, pollen grains are transferred from the anthers of a flower to the **stigma**. If this occurs within the same flower it is called **self-pollination**. If the pollen grains are transferred to a different flower, it is called **cross-pollination**. Pollination can occur by wind or by insect in either case.

Plants that are wind-pollinated produce flowers with a different structure to those of insect-pollinated flowers. These differences are related to the different methods of pollination of the flowers. Figure 13.3 shows the structure of a typical insect-pollinated flower and Figure 13.4 shows the structure of a typical wind-pollinated flower. Table 13.2 summarises the main differences between insect-pollinated flowers and wind-pollinated flowers.



▲ Figure 13.3 The main structures in an insect-pollinated flower.



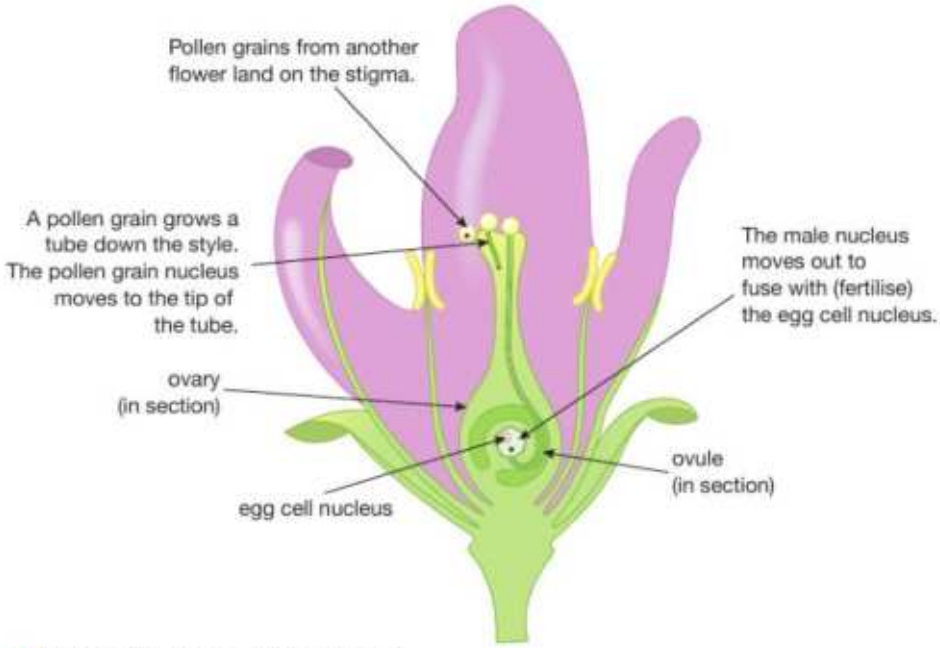
▲ Figure 13.4 The main structures in an wind-pollinated flower.

Table 13.2 Differences between insect-pollinated and wind-pollinated flowers.

Feature of flower	Type of flower	
	Insect-pollinated	Wind-pollinated
position of stamens	enclosed within flower so that insect must make contact	exposed so that wind can easily blow pollen away
position of stigma	enclosed within flower so that insect must make contact	exposed to catch pollen blowing in the wind
type of stigma	sticky so pollen grains attach from insects	feathery, to catch pollen grains blowing in the wind
size of petals	large to attract insects	small
colour of petals	brightly coloured to attract insects	not brightly coloured, usually green
nectaries	present – they produce nectar, a sweet liquid containing sugars as a 'reward' for insects	absent
pollen grains	larger, sticky grains or grains with hooks, to stick to insects' bodies	smaller, smooth, inflated grains to carry in the wind

FERTILISATION

Pollination transfers the pollen grain to the stigma. However, for fertilisation to take place, the nucleus of the pollen grain (the male gamete) must fuse with the nucleus of the ovum, which is inside an ovule in the ovary. To transfer the nucleus to the ovum, the pollen grain forms a **pollen tube**, which grows down through the tissue of the **style** and into the ovary. Here it curves around to enter the opening in an ovule. The tip of the tube dissolves and allows the pollen grain nucleus to move out of the tube and into the ovule. Here it fertilises the ovum nucleus. These events are summarised in Figure 13.5.



▲ Figure 13.5 Pollination and fertilisation

SEED AND FRUIT FORMATION

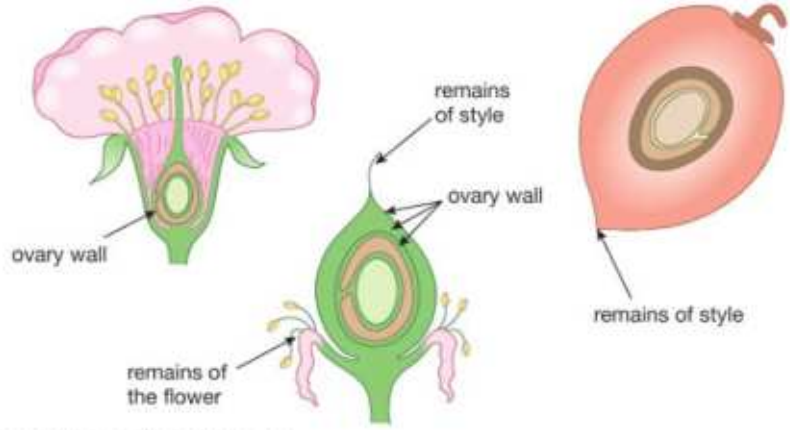
Once fertilisation has occurred, a number of changes take place in the ovule and ovary that will lead to the fertilised ovule becoming a seed and the ovary in which it is found becoming a fruit. Different flowers produce different types of fruits, but in all cases the following four changes take place.

DID YOU KNOW?

Any structure that contains seeds is a fruit. A pea pod is a fruit. The 'pod' is the fruit wall, formed from the ovary wall, and the peas are individual seeds. Each forms from a fertilised ovule.

1. The zygote develops into an embryonic plant with small root (**radicle**) and shoot (**plumule**).
2. Other contents of the ovule develop into a food store for the young plant when the seed germinates.
3. The ovule wall becomes the seed coat or **testa**.
4. The ovary wall becomes the fruit coat; this can take many forms depending on the type of fruit.

Figure 13.6 summarises these changes as they occur in the plum flower, which forms a fleshy fruit.

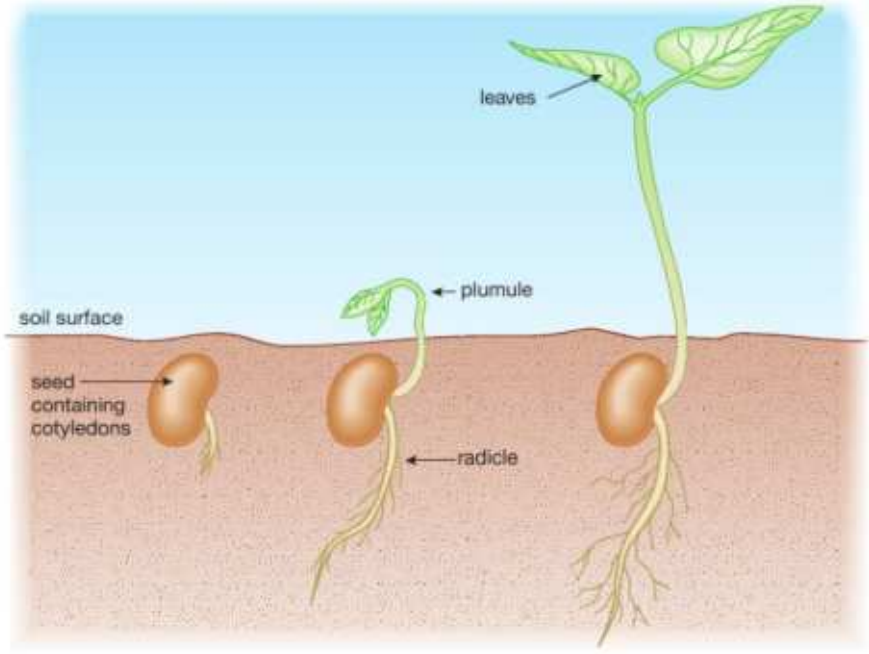


▲ Figure 13.6 How a plum fruit forms

GERMINATION

A seed contains a plant embryo, consisting of a root (radicle), shoot (plumule) and one or two seed leaves, called **cotyledons**. It also contains a food store, either in the cotyledons or another part of the seed. During germination, the food store is used up, providing the nutrients to allow the radicle and plumule to grow. The radicle grows down into the soil, where it will absorb water and mineral ions. The plumule grows upwards towards the light, where it can start the process of photosynthesis (Figure 13.7). Once the small plant (seedling) is able to photosynthesise, germination is over.

The seeds of plants such as peas or beans have two cotyledons. They are called dicotyledonous plants, or **dicots**. Seeds of grasses and other narrow-leaved plants, such as irises and orchids have only one cotyledon. They are monocotyledonous plants, or **monocots**.



▲ Figure 13.7 Germination in the broad bean. In this species, the cotyledons contain a food store. They remain below the ground when the seed germinates. In other species (e.g. the French bean), they are carried above the ground during germination.

The food store of peas or beans is present in the cotyledons. It consists mainly of starch and protein. In monocots such as maize, there is a separate food store of starch.

THE CONDITIONS NEEDED FOR GERMINATION

The growth of a new plant from a seed is called **germination**. When seeds are dispersed from the parent plant they are usually very dry, containing only about 10% water. This low water content restricts a seed's metabolism, so that it can remain alive but dormant (inactive) for a long time, sometimes for many years.

When a seed germinates, dormancy comes to an end. The seed's food store is broken down by enzymes and respired aerobically. This means that germination needs the following conditions:

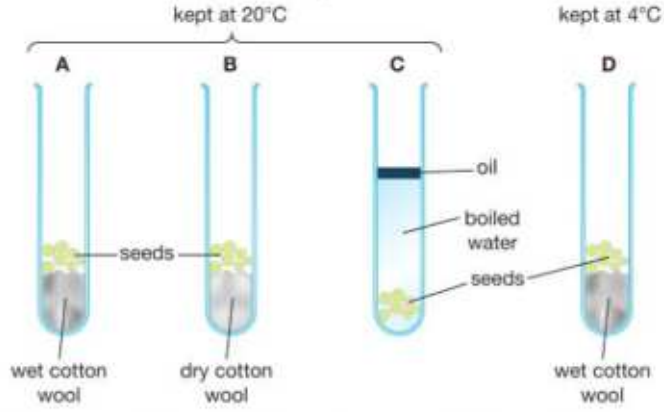
- warm temperatures, so that enzymes can act efficiently (see Chapter 1)
- water, for chemical reactions to take place in solution
- oxygen, for respiration.

Safety note: Wash hands after handling seeds.

ACTIVITY 5

▼ PRACTICAL: INVESTIGATING THE CONDITIONS NEEDED FOR GERMINATION

Small seeds such as peas or mustard will grow on wet cotton wool in a test tube. Figure 13.8 shows four tubes set up to investigate the conditions needed for the seeds to germinate.



▲ Figure 13.8 Apparatus to investigate the conditions needed for germination

The water in tube C has been boiled to remove dissolved oxygen. The layer of oil (e.g. cooking oil) keeps out oxygen from the air.

- Tube A: seeds on wet cotton wool, maintained at 20 °C (room temperature)
- Tube B: seeds on dry cotton wool, maintained at 20 °C
- Tube C: seeds in boiled water, with a thin surface layer of oil; maintained at 20 °C
- Tube D: seeds on wet cotton wool, placed in a refrigerator at 4 °C

After a few days the seeds in the control tube (A) will start to germinate. There will be no germination in tubes B or C. The seeds in tube D may eventually start to germinate, but much more slowly than in tube A.

What do the results tell you about the conditions needed for germination? Do you have any criticisms of this method? (Hint – are all the variables fully controlled?)

CHAPTER QUESTIONS

More questions on reproduction in plants can be found at the end of Unit 3 on page 159.

SKILLS CRITICAL THINKING

1 Which of the following features are shown by wind-pollinated flowers?

A large petals, a scent and sticky pollen grains
B small petals, no scent and light pollen grains
C large petals, no scent and light pollen grains
D small petals, a scent and sticky pollen grains

2 During pollination, between which of the following structures are pollen grains transferred?

A from anther to stigma
B from anther to ovary
C from stigma to style
D from stigma to ovary

SKILLS CRITICAL THINKING

3 Following fertilisation, which of the following takes place?

A The ovule becomes the fruit and the ovary becomes the seed

B The carpel becomes the fruit and the anther becomes the seed

C The anther becomes the fruit and the carpel becomes the seed

D The ovary becomes the fruit and the ovule becomes the seed

4 Read the three statements below.

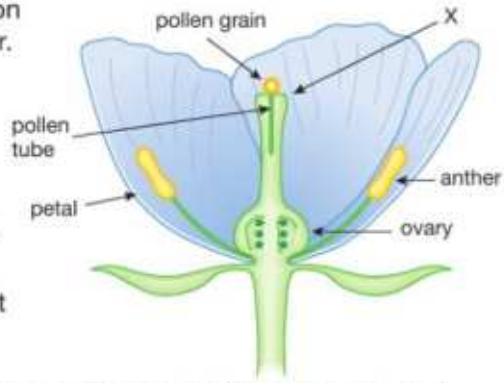
1. Uptake of water 2. Uptake of oxygen 3. Increase in metabolism

Which of these events are associated with seed germination?

A 1 and 2 **B** 1 and 3 **C** 2 and 3 **D** 1, 2 and 3

SKILLS ANALYSIS

5 The diagram below shows a section through an insect-pollinated flower. Pollination happens when pollen grains land on part X.



a Name part X.

SKILLS REASONING

b How are insects attracted to a flower like this? Give two ways.

SKILLS INTERPRETATION

c Copy the diagram and extend the pollen tube to show where it would go when fully grown.

SKILLS CRITICAL THINKING

6 A student investigated whether temperature affected the germination of seeds. He set up three boiling tubes, each containing 10 seeds placed on wet cotton wool.

- Tube A was kept at room temperature (20 °C) in the light.
- Tube B was placed in a fridge at 4 °C.
- Tube C was placed in an incubator at 30 °C.

The student monitored the seeds for 3 days, making sure that the cotton wool remained damp. At the end of this time he observed the results and measured the height of any seedlings that had germinated. His results are shown in the table.

Tube	Height of any seedlings that germinated / cm	% seeds germinated	Average height of seeds that germinated / cm
A	2.3, 2.7, 1.9, 2.5, 2.6, 3.1, 1.9, 2.2, 2.6, 3.2	100	2.5
B	0.3, 0.5 (the other seeds did not germinate)	20	0.4
C	3.4, 4.5, 2.5, 3.7, 2.8, 4.4, 4.3, 2.9, 2.1, 3.7	100	

a State the independent variable and the dependent variable in the student's experiment.

SKILLS PROBLEM SOLVING

b Calculate the average height of the seedlings that germinated in tube C.

SKILLS DECISION MAKING

c Summarise the conclusions that can be drawn from this experiment.

SKILLS REASONING

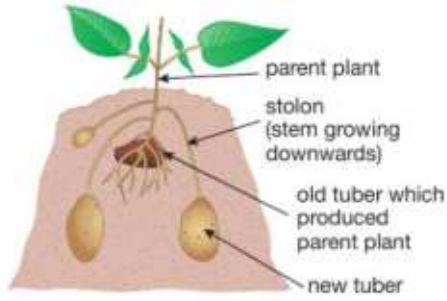
d Why does temperature affect the germination of seeds?

SKILLS EXECUTIVE FUNCTION

e Another student suggested that the experiment was not properly controlled. Explain what she meant, and suggest how the experiment could be modified.

SKILLS REASONING

7 The diagram shows a potato plant producing new tubers (potatoes). Buds on the parent plant grow into stems that grow downwards, called stolons. The ends of each stolon develop into a new tuber.



a Give two pieces of evidence which show that this is an asexual method of reproduction.

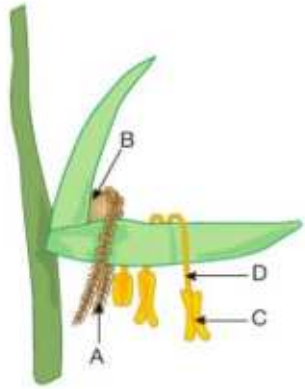
b Explain why all the new tubers will be genetically identical.

c Even though the tubers are genetically identical, the plants that grow from them may not be the same height. Explain why.

d Why do wild plants need to reproduce sexually as well as asexually?

SKILLS CRITICAL THINKING

8 The drawing shows a wind-pollinated flower.



a Name the structures labelled A, B, C and D.

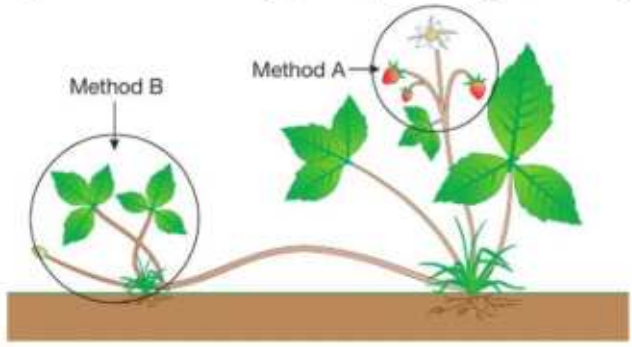
b Give *three* pieces of evidence *visible in the diagram*, which show that this flower is wind-pollinated.

c Describe how fertilisation takes place once a flower has been pollinated.

d Describe *four* ways in which you would expect an insect-pollinated flower to be different from the flower shown.

SKILLS REASONING

9 The drawing shows a strawberry plant reproducing in two ways.



a Which of the two methods of reproduction shown will result in offspring that show genetic variation? Explain your answer.

b Is the strawberry flower likely to be wind-pollinated or insect-pollinated? Give reasons for your answer.

10 All banana plants are reproduced asexually. Biologists are concerned for their future, as a new strain of fungus has appeared which is killing all the banana plants in some plantations.

a Explain why the fungus is able to kill all the banana plants in some plantations.

b Explain why this would be less likely to happen if banana plants reproduced sexually.

c Describe the benefits of reproducing banana plants asexually.

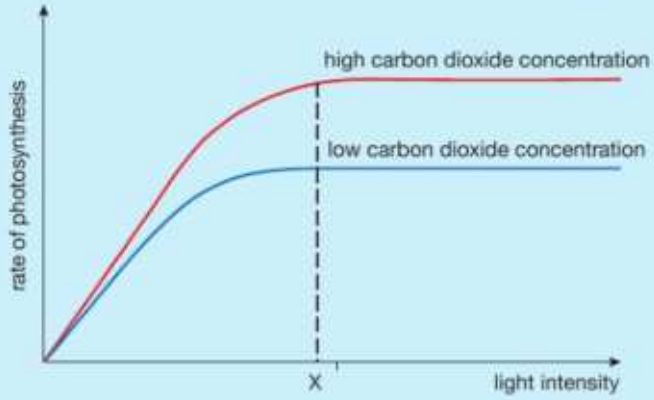
UNIT QUESTIONS

SKILLS ANALYSIS

1

Light intensity and the concentration of carbon dioxide in the atmosphere influence the rate of photosynthesis.

a The graph shows the effect of changing light intensity on the rate of photosynthesis at two different carbon dioxide concentrations.



i Describe the effect of light intensity on the rate of photosynthesis at each concentration of carbon dioxide up to light intensity X and beyond light intensity X. **(4)**

ii Which factor limits the rate of photosynthesis up to light intensity X and beyond light intensity X? **(2)**

Explain your answer in each case. **(3)**

SKILLS CRITICAL THINKING

b i Describe two other factors which influence the rate of photosynthesis. **(2)**

ii Explain why each is a limiting factor. **(4)**

SKILLS INTERPRETATION

c 'Photosynthesis is a means of converting light energy into chemical energy.'

Explain what this statement means. **(2)**

(Total 17 marks)

SKILLS DECISION MAKING

2

In an investigation to determine the water potential of potato cells, the following procedure was adopted.

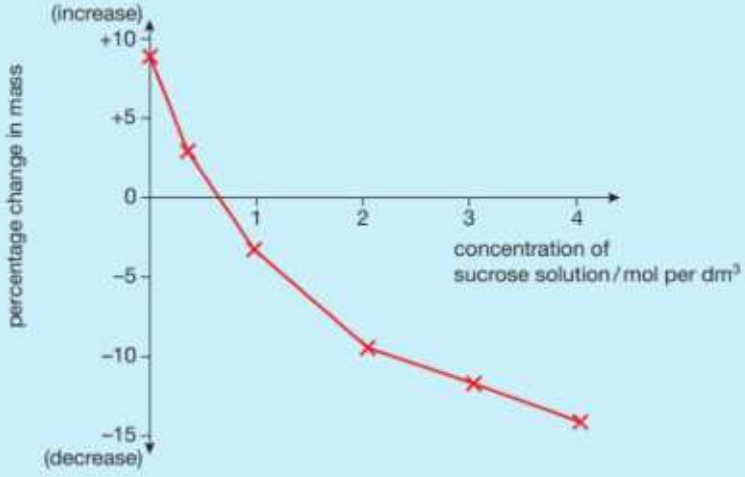
Cylinders of tissue were obtained from a potato. Each was the same diameter and cut to a length of 5 cm.

Each cylinder was dried and then weighed.

Three potato cylinders were placed in each of six different concentrations of sucrose solution and left for two hours.

The cylinders were then removed from the solutions, dried and reweighed. The percentage change in mass for each was calculated, and then an average percentage change in mass calculated for each solution.

The graph summarises the results.



a Explain why:

SKILLS DECISION MAKING

- **i** the cylinders were dried before and after being placed in the sucrose solutions **(1)**
- **ii** three cylinders were used for each solution **(1)**
- **iii** all the cylinders were the same diameter and were cut to the same length. **(1)**

SKILLS PROBLEM SOLVING

b **i** In terms of water potential, explain the result obtained with a 3 mol per dm³ sucrose solution. **(3)**

- **ii** What concentration of sucrose has a water potential equivalent to that of the potato cells? Explain your answer. **(3)**

SKILLS EXECUTIVE FUNCTION

c How could the water potential of the potato tissue be determined more accurately? **(2)**

(Total 11 marks)

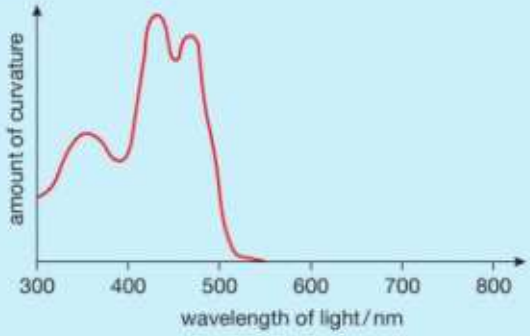
SKILLS CRITICAL THINKING

3 Plants can respond to a range of stimuli.

a Plant shoots detect and grow towards light.

- **i** What is this process called? **(1)**
- **ii** Explain how a plant bends towards the light. **(3)**
- **iii** Explain the advantage to the plant of this response. **(1)**

b In an investigation, young plant shoots were exposed to light from one side. The wavelength of the light was varied. The graph summarises the results of the investigation.



SKILLS ANALYSIS

- **i** Describe the results shown in the graph. **(2)**

SKILLS ANALYSIS 7th

ii Suggest why the results show this pattern. (2)

SKILLS CRITICAL THINKING 5th

c i Name another stimulus that produces a growth response in plants. (1)

ii Describe the ways roots and shoots respond to this stimulus (2)

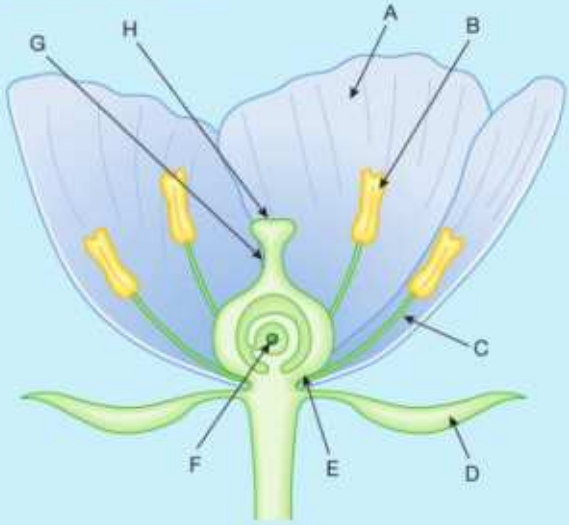
6th

iii What is the benefit to the plant of these responses? (2)

(Total 14 marks)

SKILLS ANALYSIS 4th

4 The diagram below shows a flower.



a Give the letter of the structure which:

i produces pollen grains ii becomes the seed

iii becomes the fruit wall. (3)

b Write down two ways that you can see in the diagram that this flower is adapted for insect pollination. (2)

c Give the letter of the structure which is:

i the stigma ii the style iii the filament. (3)

SKILLS INTERPRETATION 5th

d Explain the difference between:

i pollination and fertilisation

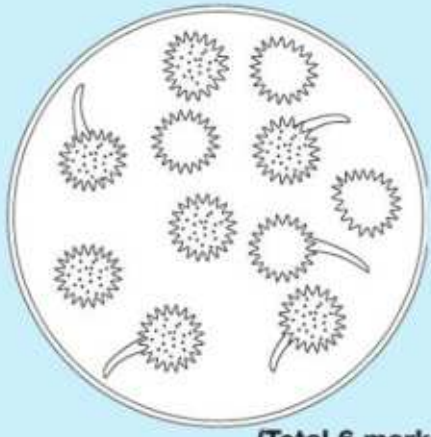
ii self-pollination and **cross-pollination**. (4)

(Total 12 marks)

SKILLS EXECUTIVE FUNCTION 8th

5 When pollen grains land on the stigma of a plant they germinate (grow a pollen tube). Growth of the pollen tube is thought to be stimulated by sugars produced by the stigma.

If pollen grains are placed in certain solutions they will germinate. The drawing shows some grains seen through a microscope after 2 hours in a solution.



Design an investigation to find out if germination of pollen grains is stimulated by sucrose.

Your answer should include experimental details and be written in full sentences.

(Total 6 marks)

ECOSYSTEMS 163 | HUMAN INFLUENCES ON THE ENVIRONMENT 176

BIOLOGY UNIT 4 ECOLOGY AND THE ENVIRONMENT

Ecology is the scientific study of the interactions between organisms and their surroundings. It analyses the interactions that living things have with each other and with their non-living, physical environment. In Chapter 14 we look at the components of ecosystems and these interactions. The activities of humans are having many serious effects on the world ecosystems, in particular as a consequence of agricultural practices and industrial pollution. Chapter 15 looks at these activities and considers how humans are damaging the planet.



14 ECOSYSTEMS

An ecosystem is a distinct, self-supporting system of organisms interacting with each other and with a physical environment. An ecosystem can be small, such as a pond, or large, such as a mangrove swamp or a large forest. This chapter looks at a variety of ecosystems and the interactions that happen within them.

LEARNING OBJECTIVES

- Understand the terms ecosystem, habitat, population and community
- Investigate the population size of an organism in two different areas using quadrats
- Understand how biotic and abiotic factors affect the population size and distribution of organisms
- Understand the names given to different trophic levels, including producers, primary, secondary and tertiary consumers, and decomposers
- Understand the concepts of food chains, food webs, pyramids of number, pyramids of biomass and pyramids of energy transfe
- Understand the transfer of substances and energy along a food chain
- Understand why only about 10% of energy is transferred from one trophic level to the next
- Describe the stages in the carbon cycle, including respiration, photosynthesis, decomposition and combustion



▲ Figure 14.1 A pond is a small ecosystem.



▲ Figure 14.2 A mangrove swamp is a larger ecosystem.

THE COMPONENTS OF ECOSYSTEMS

Whatever their size, **ecosystems** usually have the same components:

- **producers** – plants which photosynthesise to produce food
- **consumers** – animals that eat plants or other animals
- **decomposers** – organisms that break down dead material and help to recycle nutrients
- the physical environment – all the non-biological components of the ecosystem; for example, the water and soil in a pond or the soil and air in a forest.

KEY POINT

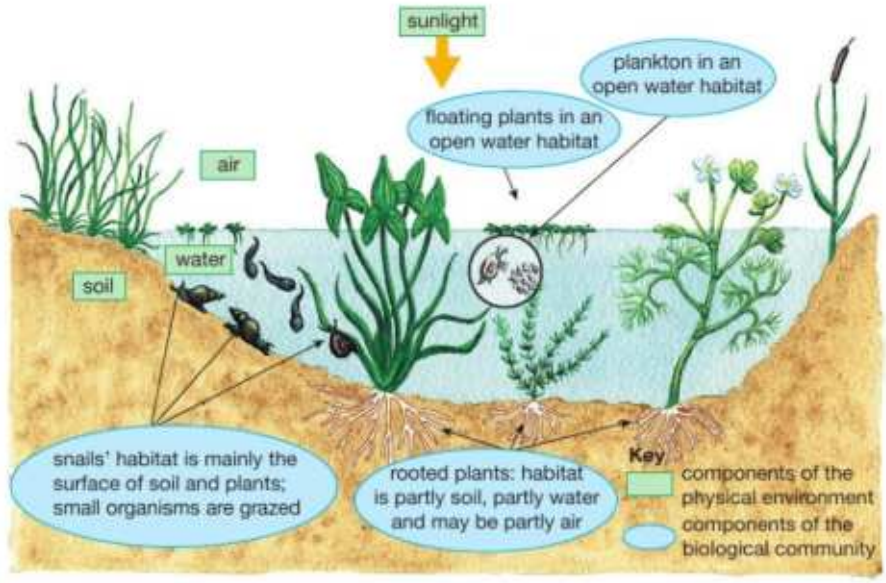
Decomposers are fungi and some species of bacteria. They feed by saprotrophic nutrition (see Chapter 2)

The living components of an ecosystem are called the *biotic* components. The non-living (physical) components are the *abiotic* components (compare these with **biotic** and **abiotic factors**, below).

An ecosystem contains a variety of habitats. A **habitat** is the place where an organism lives. For example, habitats in a pond ecosystem include the open water, the mud at the bottom of the pond, and the surface water.

All the organisms of a particular species found in an ecosystem at a certain time form the **population** of that species. All the immature frogs (tadpoles) swimming in a pond are a population of tadpoles; all the water lily plants growing in the pond make up a population of water lilies.

The populations of *all* species (animals, plants and other organisms) found in an ecosystem at a particular time form the **community**. Figure 14.3 illustrates the main components of a pond ecosystem.



▲ Figure 14.3 A pond ecosystem

USING QUADRATS TO SAMPLE FROM A HABITAT

HINT

People often mistakenly call quadrats 'quadrants'. A *quadrant* is quite different – it is a quarter of a circle.

When an ecologist wants to know how many organisms there are in a particular habitat, it would not be possible for him to count them all. Instead, he is forced to count a smaller representative part of the population, called a *sample*. Sampling of plants, or animals that do not move much (such as snails), can be done using a sampling square called a **quadrat**. A quadrat is usually made from metal, wood or plastic. The size of quadrat you use depends on the size of the organisms being sampled. For example, to count plants growing on a school field, you could use a quadrat with sides 0.5 or 1 metre in length (Figure 14.4).



▲ Figure 14.4 A student sampling with a quadrat

KEY POINT

Some books (and teachers!) talk about 'throwing' quadrats. The idea is that you stand in the middle of a field and throw the quadrat over your shoulder. This is supposed to be random, but it isn't! The place where the quadrat falls will depend on where you stand, how hard you throw it, etc. It is wrong to use this method.

It is important that sampling in an area is carried out *at random*, to avoid bias. For example, if you were sampling from a school field, but for convenience only placed your quadrats next to a path, this probably wouldn't give you a sample that was representative of the whole field! It would be a *biased* sample.

ACTIVITY 1

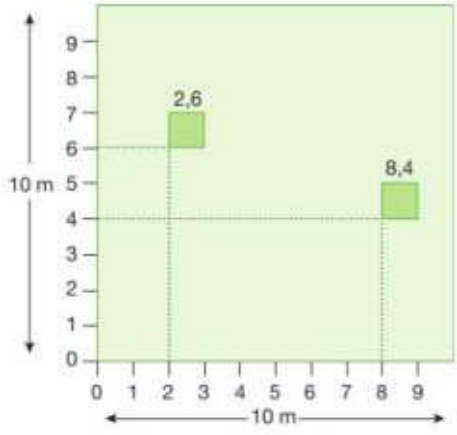
▼ PRACTICAL: USING QUADRATS TO COMPARE THE SIZE OF A PLANT POPULATION IN TWO AREAS OF A FIELD

Safety note: Wash hands after handling the quadrat, plants and soil. Take care if working near a pond or stream or in any areas which may contain animal faeces.

One way that you can sample randomly is to place quadrats at coordinates on a numbered grid.

Imagine that there are two areas of a school field (A and B) that seem to contain different numbers of dandelion plants. Area A is more trampled than area B and looks like it contains fewer dandelions. This might lead you to propose the hypothesis: 'The dandelion population in area A is smaller than the dandelion population in area B'.

In area A, two 10-metre tape measures are arranged to form the sides of a square (Figure 14.5).



▲ Figure 14.5 A 10-m² grid with 1-m² quadrats positioned at coordinates 2,6 and 8,4.

A pair of random numbers is generated, using the random number function on a calculator. These numbers are used as coordinates to position the quadrat in the large square.

The numbers of dandelions in the quadrat are counted. The process is then repeated for nine more quadrats.

The tape measures are then moved to area B and the process repeated to sample from ten more quadrats in that part of the field.

The table below shows a set of results for a study like this.

Table 14.1

Quadrat number	Number of dandelions in each quadrat in area A	Number of dandelions in each quadrat in area B
1	4	10
2	7	7
3	1	9
4	0	14
5	3	12
6	8	7
7	3	16
8	12	9
9	1	11
10	6	15

Calculate the mean number of dandelions per m^2 in each area. Do the results support the hypothesis that the population numbers are different? How could you improve the **reliability** of the results?

INTERACTIONS IN ECOSYSTEMS

The organisms in an ecosystem are continually interacting with each other and with their physical environment. Interactions include the following.

- Feeding among the organisms – the plants, animals and decomposers are continually recycling the same nutrients through the ecosystem.
- Competition among the organisms – animals compete for food, shelter, mates, nesting sites; plants compete for carbon dioxide, mineral ions, light and water.
- Interactions between organisms and the environment – plants absorb mineral ions, carbon dioxide and water from the environment; plants also give off water vapour and oxygen into the environment; animals use materials from the environment to build shelters; the temperature of the environment can affect processes occurring in the organisms; processes occurring in organisms can affect the temperature of the environment (all organisms produce some heat).

REMINDER

Don't forget that plants take in carbon dioxide and give out oxygen only when there is sufficient light for photosynthesis to occur efficiently. When there is little light, plants take in oxygen and give out carbon dioxide. You should be able to explain the reasons for this (see Chapter 10).

BIOTIC AND ABIOTIC FACTORS

There are many factors that influence the numbers and distribution of organisms in an ecosystem. There are two types of factor – *biotic* and *abiotic*.

Biotic factors are biological. Many (but not all) involve feeding relationships. They include:

- availability of food and competition for food resources
- predation
- parasitism
- disease
- presence of pollinating insects
- availability of nest sites.

KEY POINT

A **predator** is an animal that kills and eats another animal. A **parasite** is an organism (animal or plant) that lives in or on another organism (called its host) and gets its nutrition from the host. e.g. mosquitoes are parasites of humans (and other animals), and the human is the host of the mosquito.

Abiotic factors are physical or chemical factors. They include:

- climate, such as light intensity, temperature and water availability
- hours of daylight
- soil conditions, such as clay content, nitrate level, particle size, water content and pH
- other factors specific to a particular habitat, such as salinity (salt content) in an estuary, flow rate in a river, or oxygen concentration in a lake
- pollution.

Clearly *which* factors affect population sizes and distribution of organisms will depend on the *type* of ecosystem. If you take the example of a river, some of the main abiotic factors could be:

- depth of water
- flow rate
- type of material at the bottom of the stream (stones, sand, mud etc.)
- concentration of minerals in the water
- pH
- oxygen concentration
- cloudiness of the water
- presence of any pollution.

The main biotic factors affecting animals in the river will be food supply, either from plants or other animals. But other factors are important too – large fish could not live in a shallow stream!

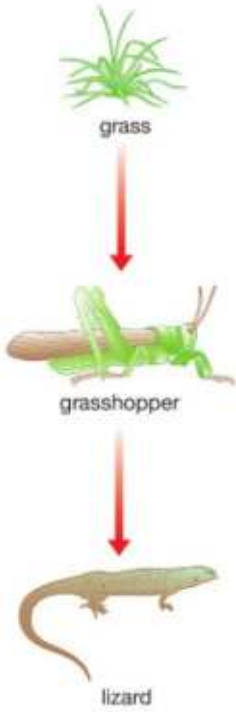
It is impossible to generalise about which factors are the most important. In a heavily polluted river all the organisms could be killed by the pollution, while in a clean river depth and flow rate might have a greater effect on the animals that could live there. The different factors may also affect one another. For example, a faster flow rate could mix the water with air, increasing the amount of dissolved oxygen.

KEY POINT

Large areas of the Earth dominated by a specific type of vegetation are called *biomes*. Temperate grassland and tropical rain forest are two examples of biomes. You could carry out some research to find out about these and other biomes.

The main factor affecting large ecosystems is climate, particularly temperature and rainfall. Climate is the reason why **tropical rainforests** are restricted to a strip near the equator of the Earth, while pine forests grow in the higher latitudes of the northern hemisphere.

FEEDING RELATIONSHIPS



▲ Figure 14.6 A simple food chain.

The simplest way of showing feeding relationships within an ecosystem is a **food chain** (Figure 14.6).

In any food chain, the arrow (→) means 'is eaten by'. In the food chain illustrated, the grass is the **producer**. It is a plant so it can photosynthesise and produce food materials. The grasshopper is the **primary consumer**. It is an animal which eats the producer and is also a **herbivore**. The lizard is the **secondary consumer**. It eats the primary consumer and is also a **carnivore**. The different stages in a food chain (producer, primary consumer and secondary consumer) are called **trophic levels**.

Many food chains have more than three links in them. Here are two examples of longer food chains:

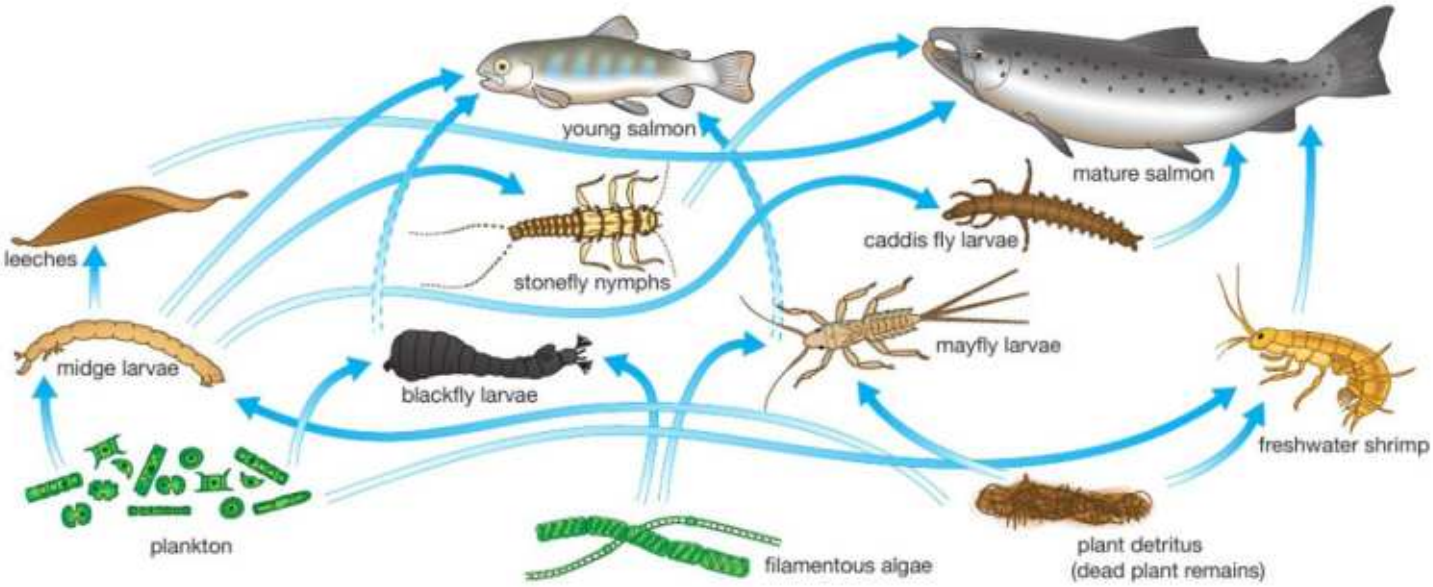
filamentous algae → mayfly nymph → caddis fly larvae → salmon

In this freshwater food chain, the extra link in the chain makes the salmon a **tertiary consumer**.

plankton → crustacean → fish → ringed seal → polar bear

In this marine (sea) food chain, the fifth link makes the polar bear a **quaternary consumer**. Because nothing eats the polar bear, it is also called the *top carnivore*.

Food chains are a convenient way of showing the feeding relationships between a few organisms in an ecosystem, but they oversimplify the situation. The marine food chain above implies that only crustaceans feed on plankton, which is not true. Some whales and other mammals also feed on plankton. For a fuller understanding, you need to consider how the different food chains in an ecosystem relate to each other. Figure 14.7 gives a clearer picture of the feeding relationships involved in a freshwater ecosystem in which salmon are the top carnivores. This is the **food web** of the salmon.



▲ Figure 14.7 The food web of the salmon. As you can see, young salmon have a slightly different diet to mature salmon.

This is still an oversimplification of the true situation, as some feeding relationships are still not shown. It does, however, give some indication of the interrelationships that exist between food chains in an ecosystem. With a little thought, you can predict how changes in the numbers of an organism in one food chain in the food web might affect those in another food chain. For example, if the leech population were to decline through disease, there could be several possible consequences:

- the stonefly nymph population could increase as there would be more midge larvae to feed on
- the stonefly nymph population could decrease as the mature salmon might eat more of them as there would be fewer leeches
- the numbers could remain the same due to a combination of the above.

Although food webs give us more information than food chains, they don't give any information about how many, or what mass of organisms is involved. Neither do they show the role of the decomposers. To see this, we must look at other ways of presenting information about feeding relationships in an ecosystem.

ECOLOGICAL PYRAMIDS

Ecological pyramids are diagrams that represent the relative amounts of organisms at each trophic level in a food chain. There are two main types:

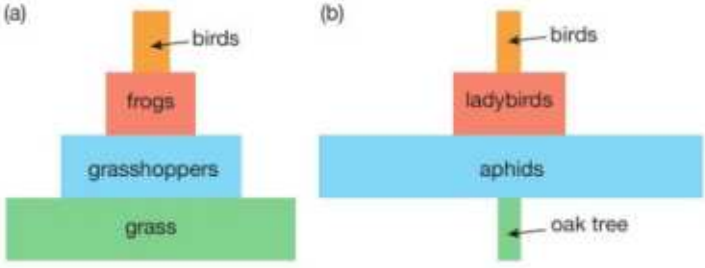
- **pyramids of numbers**, which represent the numbers of organisms in each trophic level in a food chain, irrespective of their mass
- **pyramids of biomass**, which show the total mass of the organisms in each trophic level, irrespective of their numbers.

Consider these two food chains:

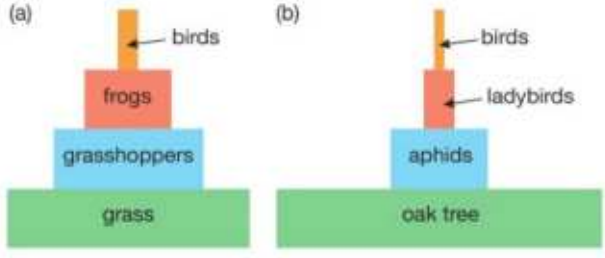
a grass → grasshopper → frog → bird

b oak tree → aphid → ladybird → bird

Figures 14.8 and 14.9 show the pyramids of numbers and biomass for these two food chains.



▲ Figure 14.8 Pyramids of numbers for two food chains



▲ Figure 14.9 Pyramids of biomass for the two food chains

KEY POINT

Biomass is the total mass of organisms. If it refers to living organisms, this is called the *fresh biomass*. More commonly the *dry biomass* is used. This is the mass of plant or animal material after water has been removed, by drying in an oven. Dry biomass is a more reliable measure, since the water content of organisms (especially plants) varies with environmental conditions.

The two pyramids for the 'grass' food chain look the same – the numbers at each trophic level decrease. The *total* biomass also decreases along the food chain – the mass of *all* the grass plants in a large field would be more than that of *all* the grasshoppers which would be more than that of *all* the frogs, and so on.

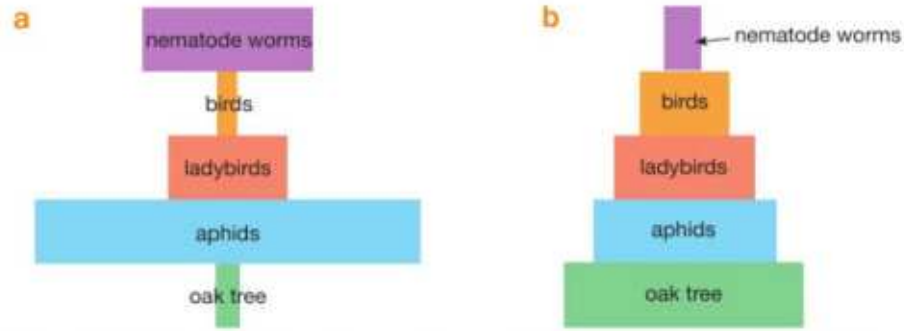
The two pyramids for the 'oak tree' food chain look different because of the size of the oak trees. Each oak tree can support many thousands of aphids, so the numbers *increase* from first to second trophic levels. But each ladybird will need to eat many aphids and each bird will need to eat many ladybirds, so the numbers *decrease* at the third and fourth trophic levels. However, the total biomass *decreases* at each trophic level – the biomass of one oak tree is much

greater than that of the thousands of aphids it supports. The total biomass of all these aphids is greater than that of the ladybirds, which is greater than that of the birds.

Suppose the birds in the second food chain are parasitised by nematode worms (small worms living in the bird's gut). The food chain now becomes:

oak tree → aphid → ladybird → bird → nematode worm

The pyramid of numbers now takes on a very strange appearance (Figure 14.10a) because of the large numbers of parasites on each bird. The pyramid of biomass, however, has a true pyramid shape because the total biomass (Figure 14.10b) of the nematode worms must be less than that of the birds they parasitise.



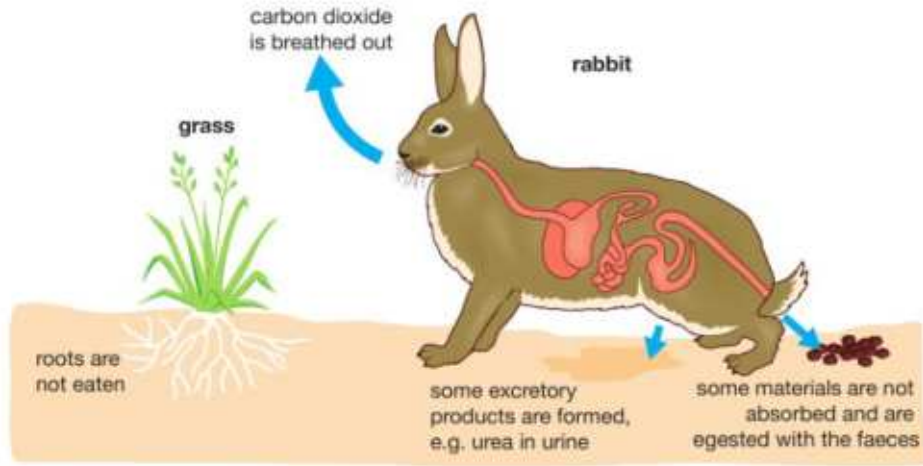
▲ Figure 14.10 (a) A pyramid of numbers and (b) a pyramid of biomass for the parasitised food chain.

KEY POINT

Another way of describing the food chain is that it shows how energy is moved from one organism to another as a result of feeding. The arrows show the direction of energy flow.

The explanation is relatively straightforward (Figure 14.11). When a rabbit eats grass, not all of the materials in the grass plant end up as rabbit! There are losses:

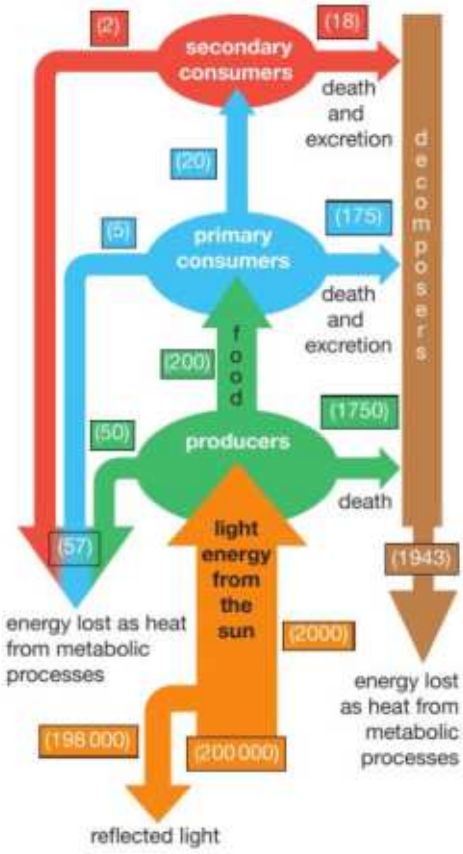
- some parts of the grass are not eaten (the roots for example)
- some parts are not digested and so are not absorbed – even though rabbits have a very efficient digestive system
- some of the materials absorbed form excretory products
- many of the materials are respired to release energy, with the loss of carbon dioxide and water.



▲ Figure 14.11 Not all the grass eaten by a rabbit ends up as rabbit tissue.

In fact, only a small fraction of the materials in the grass ends up in new cells in the rabbit. Similar losses are repeated at each stage in the food chain, so smaller and smaller amounts of biomass are available for growth at successive trophic levels. The shape of pyramids of biomass reflects this.

Feeding is a way of transferring energy between organisms. Another way of modelling ecosystems looks at the energy flow between the various trophic levels.



All figures given are kilojoules ($\times 10^5$) per m^2 per year.

▲ Figure 14.12 The main ways in which energy is transferred in an ecosystem. The amounts of energy transferred through 1 m^2 of a grassland ecosystem per year are shown in brackets.

THE FLOW OF ENERGY THROUGH ECOSYSTEMS

This approach focuses less on individual organisms and food chains and rather more on energy transfer between trophic levels (producers, consumers and decomposers) in the whole ecosystem. There are a number of key ideas involved:

- Photosynthesis 'fixes' sunlight energy into chemicals such as glucose and starch.
- Respiration releases energy from organic compounds such as glucose.
- Almost all other biological processes (e.g. muscle contraction, growth, reproduction, excretion, active transport) use the energy released in respiration.
- If the energy released in respiration is used to produce new cells, then the energy remains 'fixed' in molecules in that organism. It can be passed on to the next trophic level through feeding.
- If the energy released in respiration is used for other processes then it will, once used, eventually escape as heat from the organism. Energy is therefore lost from food chains and webs at each trophic level.

Figure 14.12 is an energy flow diagram. It shows the main ways in which energy is transferred in an ecosystem. It also gives the amounts of energy transferred between the trophic levels of this particular (grassland) ecosystem.

As you can see, only about 10% of the energy entering a trophic level is passed on to the next trophic level. This explains why not many food chains have more than five trophic levels. Think of the food chain:

$$A \rightarrow B \rightarrow C \rightarrow D \rightarrow E$$

If we use the idea that only about 10% of the energy entering a trophic level is passed on to the next level, then, of the original 100% reaching A (a producer), 10% passes to B, 1% (10% of 10%) passes to C, 0.1% passes to D and only 0.001% passes to E. There just isn't enough energy left for another trophic level. In certain parts of the world, some marine food chains have six trophic levels because of the huge amount of light energy reaching the surface waters.

CYCLING NUTRIENTS THROUGH ECOSYSTEMS

The chemicals that make up our bodies have all been around before – probably many times! You may have in your body some carbon atoms that were part of the body of Mahatma Gandhi or were in carbon dioxide molecules breathed out by Winston Churchill. This constant recycling of substances is all part of the cycle of life, death and decay.

Microorganisms play a key role in recycling. They break down complex organic molecules in the bodies of dead animals and plants into simpler substances, which they release into the environment.

THE CARBON CYCLE

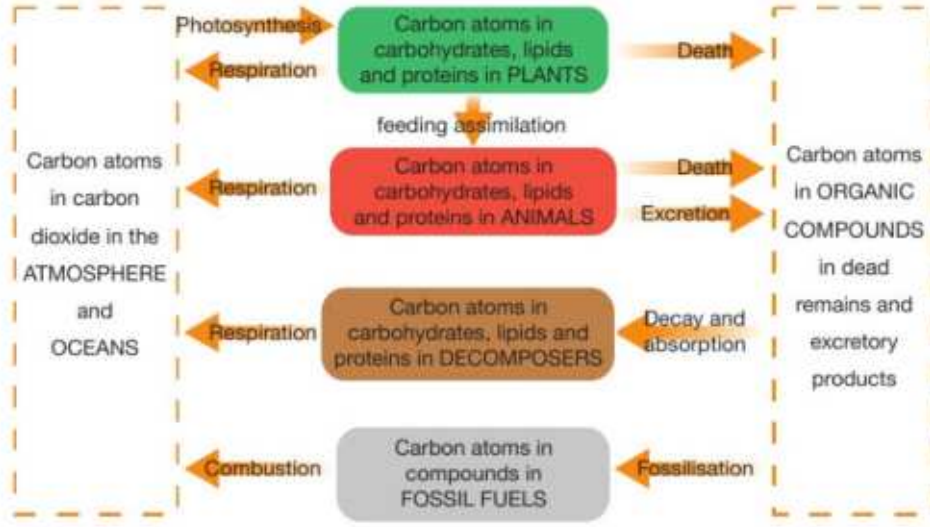
DID YOU KNOW?

What exactly is an organic compound? There is no precise definition! All organic compounds contain carbon, and *most* contain hydrogen. Starch and glucose are organic molecules, but carbon dioxide (CO_2) isn't (it is inorganic).

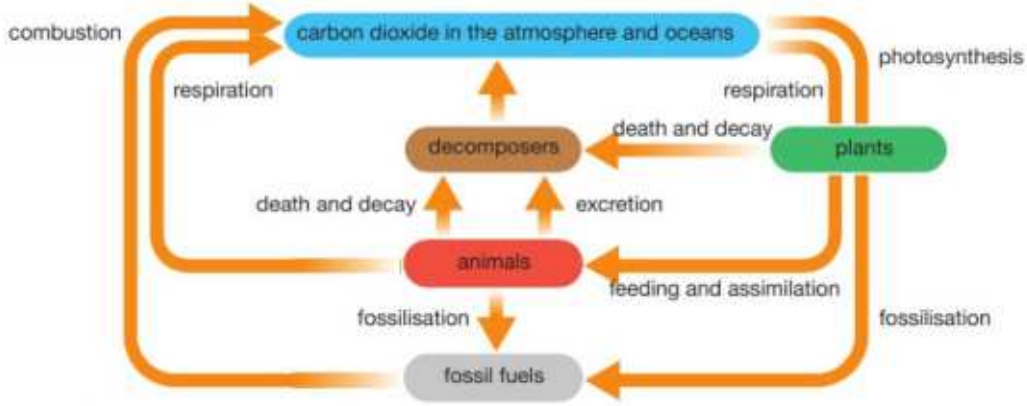
Carbon is a component of all major biological molecules. Carbohydrates, lipids, proteins, DNA, vitamins and many other molecules all contain carbon. The following processes are important in cycling carbon through ecosystems.

- Photosynthesis 'fixes' carbon atoms from carbon dioxide into organic compounds
- Feeding and **assimilation** pass carbon atoms already in organic compounds along food chains
- Respiration produces inorganic carbon dioxide from organic compounds (mainly carbohydrates) as they are broken down to release energy
- Fossilisation – sometimes living things do not decay fully when they die due to the conditions in the soil (decay is prevented if it is too acidic) and fossil fuels (coal, oil, natural gas and peat) are formed
- Combustion releases carbon dioxide into the atmosphere when fossil fuels are burned.

Figures 14.13 and 14.14 show the role of these processes in the carbon cycle in different ways.



▲ Figure 14.13 The main stages in the carbon cycle



▲ Figure 14.14 A typical illustration of the carbon cycle

LOOKING AHEAD – MEASURING BIODIVERSITY

Ecology is a very mathematical branch of biology. An example of this is that **biodiversity** can be measured by calculating a *diversity index*. One example is called Simpson's Index. One formula for Simpson's Index (D) is:

$$D = 1 - \sum\left(\frac{n}{N}\right)^2$$

In this formula:

N = the total number of individuals of all species

n = the total number of individuals of a particular species.

You calculate $\frac{n}{N}$ for each species, square each of these numbers, and then sum (Σ) all the squares. Subtracting this value from 1 gives you D. Values of D range from 0 to 1, where 0 represents a low diversity and 1 a high diversity.

Take the data you saw in Table 14.1:

Species	Number of individuals of each species in community 1	Number of individuals of each species in community 2
A	10	1
B	10	1
C	10	1
D	10	1
E	10	46

For community 1:

The total number of individuals of all species (N) = 50

For each species the total number of individuals (n) = 10.

So $\frac{n}{N} = \frac{10}{50} = 0.2$ for each species

$$\sum\left(\frac{n}{N}\right)^2 = \left(\frac{10}{50}\right)^2 + \left(\frac{10}{50}\right)^2 + \left(\frac{10}{50}\right)^2 + \left(\frac{10}{50}\right)^2 + \left(\frac{10}{50}\right)^2$$

$$= 0.22 + 0.22 + 0.22 + 0.22 + 0.22$$

$$= 0.04 + 0.04 + 0.04 + 0.04 + 0.04$$

$$= 0.20$$

To find Simpson's Index you subtract this value from 1:

$D = (1 - 0.20) = 0.80$

This value is close to 1.0, showing that community 1 has a high biodiversity.

Can you calculate Simpson's Index for community 2? If you do it carefully you should get the answer $D = 0.152$, showing that community 2 has a lower biodiversity.

EXTENSION WORK

If you are interested, you can do some background research about Simpson's Index. You will find that there are different formulae used for the Index. It doesn't matter which one you use, as long as you are consistent.

CHAPTER QUESTIONS

More questions on ecosystems can be found at the end of Unit 4 on page 191.

SKILLS CRITICAL THINKING

1 Which of the following terms is defined as 'all the organisms living in a particular place and their interactions with each other and with their environment'?

A habitat

B population

C community

D ecosystem

2 Which of the following is a biotic factor?

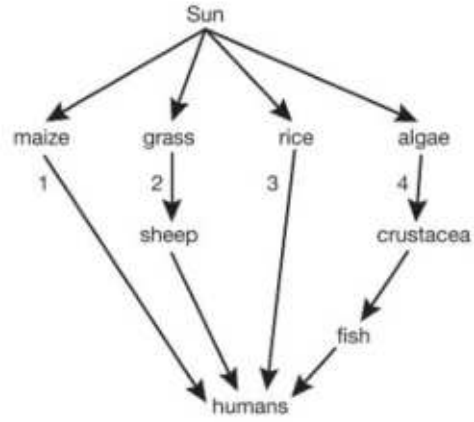
A light intensity

B food supply

C pollution

D temperature

3 The diagram below shows a food web containing four food chains.



Which food chains are most efficient at using energy from the Sun?

A 1 and 3

B 2 and 4

C 2 and 3

D 3 and 4

4 a Explain what is meant by the terms habitat, community, environment and population.

b What are the roles of plants, animals and decomposers in an ecosystem?

5 A marine food chain is shown below.

plankton → small crustacean → krill → seal → killer whale

a Which organism is i the producer, ii the secondary consumer?

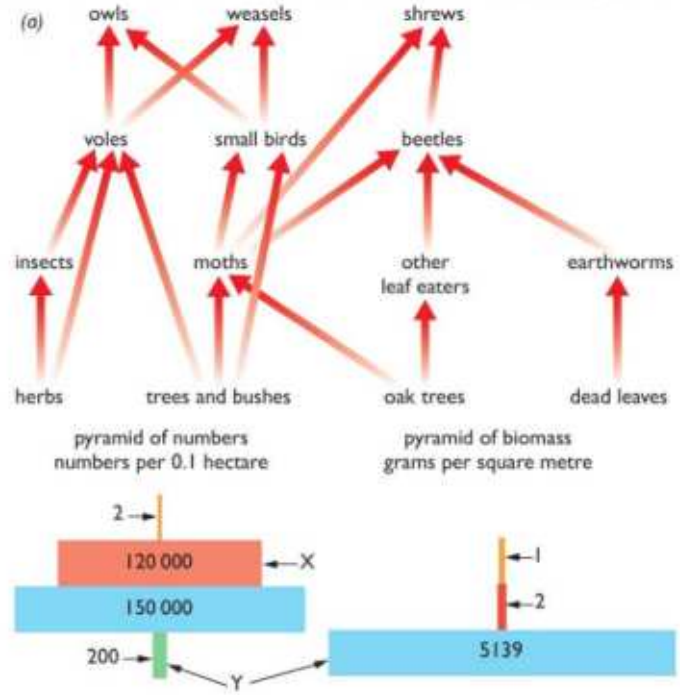
b What term best describes the killer whale?

SKILLS REASONING

c Suggest why five trophic levels are possible in this case, when many food chains only have three or four.

SKILLS INTERPRETATION

6 Part *(a)* of the diagram shows a woodland food web. Part *(b)* shows a pyramid of numbers and a pyramid of biomass for a small part of this wood.



a Write out *two* food chains (from the food web) containing four organisms, both involving moths.

b Name *one* organism in the food web which is both a primary consumer and a secondary consumer.

SKILLS REASONING

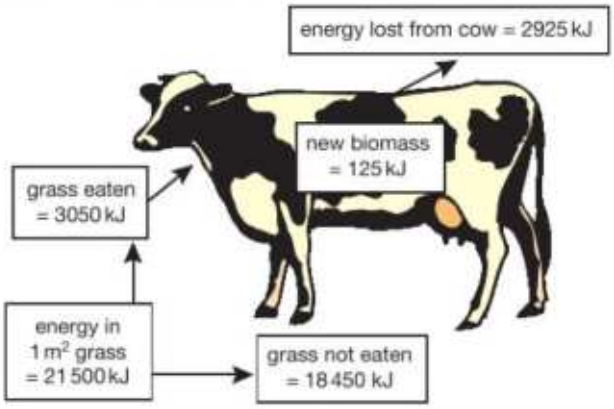
c Suggest how a reduction in the dead leaves may lead to a reduction in the numbers of shrews.

SKILLS ANALYSIS, REASONING

d In part *(b)* of the diagram, explain why level Y is such a different width in the two pyramids.

SKILLS PROBLEM SOLVING

7 In a year, 1 m^2 of grass produces 21 500 kJ of energy. The diagram below shows the fate of the energy transferred to a cow feeding on the grass.



a Calculate the energy efficiency of the cow from the following equation.

$$\text{Energy efficiency} = \frac{\text{energy that ends up as part of cow's biomas}}{\text{energy available}} \times 100$$

b State two ways that energy is lost from the cow.

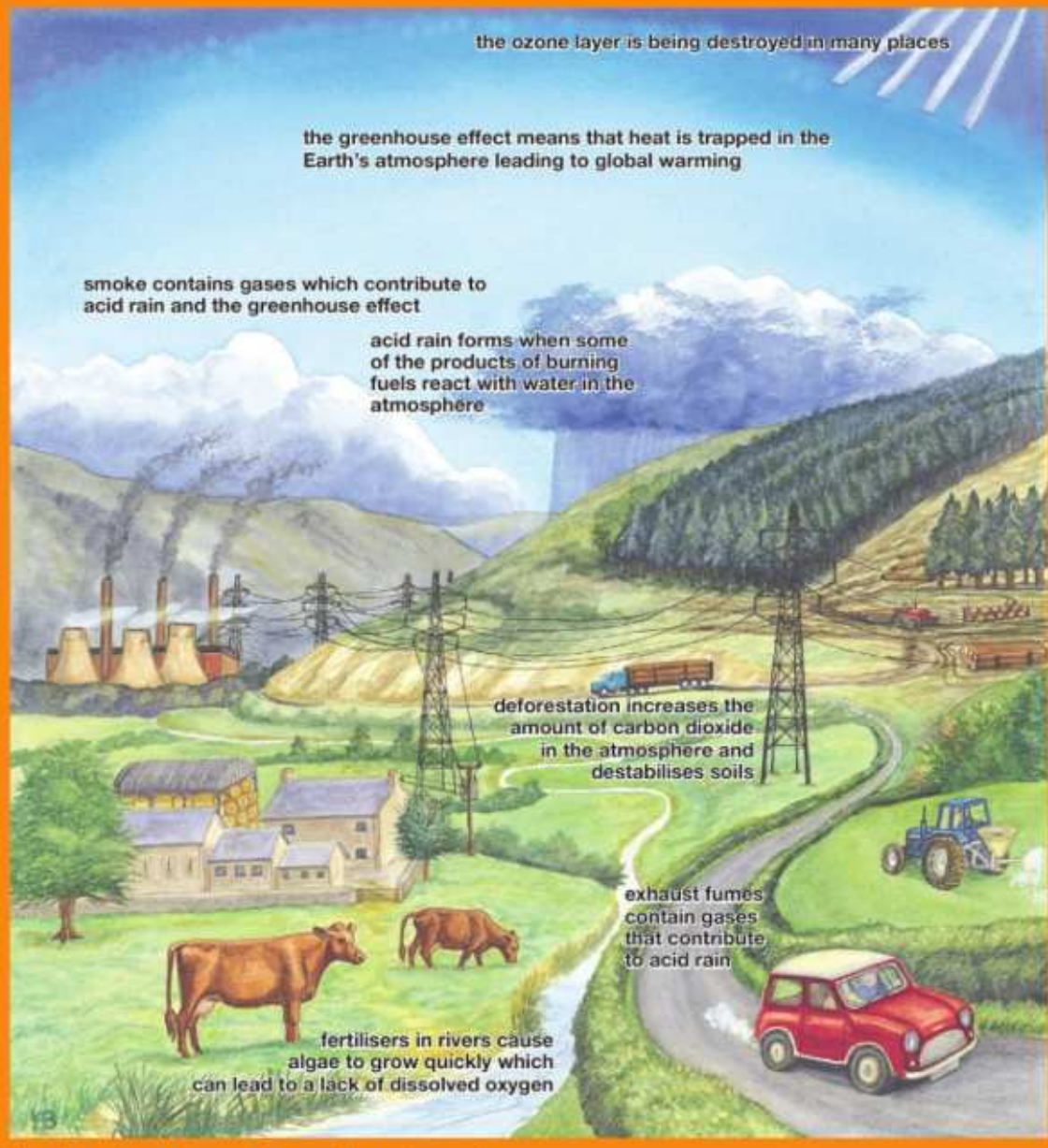
SKILLS CRITICAL THINKING

SKILLS REASONING

c Suggest what may happen to the 18 450 kJ of energy in the grass that was not eaten by the cow.

15 HUMAN INFLUENCES ON THE ENVIRONMENT

Humans have intelligence far beyond that of any other animal on Earth. This chapter looks at the ways in which we have used our intelligence to influence natural environments, and some of the problems we have caused.

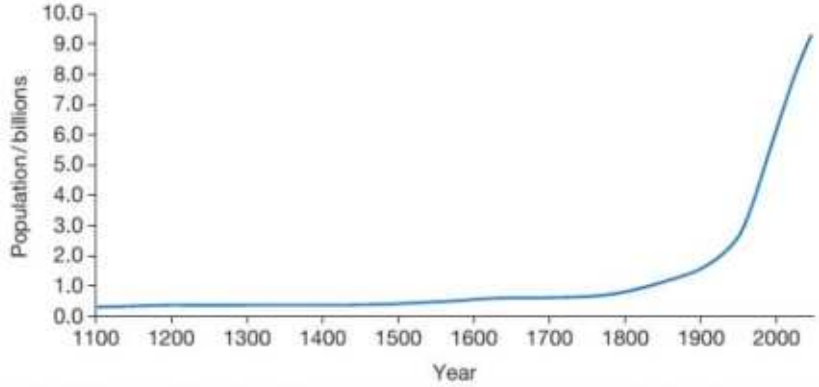


▲ Figure 15.1 How the actions of humans influence the environment.

LEARNING OBJECTIVES

- Describe how glasshouses and polythene tunnels can be used to increase the yield of certain crops
- Understand the effects on crop yield of increased carbon dioxide and increased temperature in glasshouses
- Understand how the use of fertiliser can increase crop yield
- Understand the reasons for pest control and the advantages and disadvantages of using pesticides and biological control with crop plants
- Understand that water vapour, carbon dioxide, nitrous oxide, methane and CFCs are greenhouse gases
- Understand how human activities contribute to greenhouse gases
- Understand how an increase in greenhouse gases results in an enhanced greenhouse effect and that this may lead to global warming and its consequences
- Understand the biological consequences of pollution of air by sulfur dioxide and carbon monoxide
- Understand the biological consequences of pollution of water by sewage
- Understand the biological consequences of eutrophication caused by leached minerals from fertiliser

Since humans first appeared on Earth, our numbers have grown dramatically (Figure 15.2). The secret of our success has been our intelligence. Unlike other species, we have not adapted to one specific environment, we have changed many environments to suit our needs.



▲ Figure 15.2 The rate of increase of the human population has been particularly steep over the last 200 years. The curve has been extended to 2050, showing that the population is expected to reach 10 billion by that date..

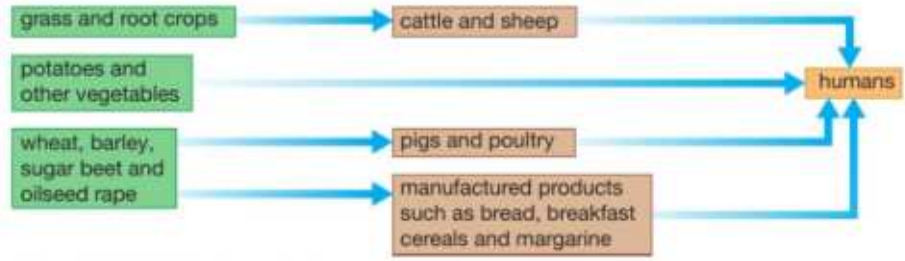
As our numbers have grown, so has the sophistication of our technology. Early humans made tools from materials readily to hand. Today's technology involves much more complex processes. As a result, we produce ever-increasing amounts of materials that pollute our air, soil and waterways.

Early humans influenced their environment, but the enormous size of the population today and the extent of our industries mean that we affect the environment much more significantly. We make increasing demands on the environment for:

- food to sustain an ever-increasing population
- materials to build homes, schools and industries
- fuel to heat homes and power vehicles
- space in which to build homes, schools and factories, as well as for leisure facilities
- space in which to dump our waste materials.

MODERN AGRICULTURE – PRODUCING THE FOOD WE NEED

A modern farm is a sort of managed ecosystem. Many of the interactions are the same as in natural ecosystems. Crop plants depend on light and mineral ions from the soil as well as other factors in the environment. Stock animals (sheep, cattle, etc.) depend on crop plants for food (see Figure 15.3).



▲ Figure 15.3 A food web on a farm

Farmers must make a profit from their farms. To do this, they try to control the environment in such a way as to maximise the yield from crop plants and livestock.

IMPROVING YIELDS FROM CROP PLANTS

Table 15.1 summaries some factors that can be controlled by the farmer in order to maximise crop yield.

DID YOU KNOW?

Soil pH can vary between about pH 3 to 8. Soil pH is tested using indicator kits or pH meters. Some soils are too acidic – they can be made more alkaline by adding lime.

Table 15.1 Some ways the yield from crops can be improved.

Factor controlled	How it is controlled	Reason for controlling the factor
soil ions (e.g. nitrates)	adding fertilisers to the soil or growing in a hydroponic culture (Figure 15.4a)	extra mineral ions can be taken up and used to make proteins and other compounds for growth
soil structure	ploughing fields to break up compacted soil; adding manure to improve drainage and aeration of heavy, clay soils	good aeration and drainage allow better uptake of mineral ions (by active transport) and water
soil pH	adding lime (calcium salts) to acidic soils; few soils are too alkaline to need treatment	soil pH can affect crop growth as an unsuitable pH reduces uptake of mineral ions
carbon dioxide, light and heat	these cannot be controlled for field crops but in a glasshouse or polytunnel all can be altered to maximise yield of crops (Figure 15.4b); burning fuels produces heat and carbon dioxide	all may limit the rate of photosynthesis and the production of the organic substances needed for growth



▲ Figure 15.4 (a) A glasshouse maintains a favourable environment for plants. Crops grown by hydroponics in a glasshouse.

Glasshouses (otherwise known as 'greenhouses') and polytunnels can provide very controlled conditions for plants to grow (Figure 15.4). There are several reasons for this.

- The transparent walls of the glasshouse allow enough natural light for photosynthesis during the summer months, while additional lighting gives a 'longer day' during the winter.



▲ Figure 15.4 (b) Many crops are grown in large tunnels made of transparent polythene, called polytunnels.

- The 'greenhouse effect' doesn't just happen to the Earth, but also in greenhouses! Short wavelength infrared radiation entering the glasshouse is absorbed and re-radiated as longer wavelength infrared radiation. This radiation cannot escape through the glass, so the glasshouse heats up (see the section on the Earth's greenhouse effect later in this chapter). The glasshouse also reduces convection currents that would cause cooling.
- The glasshouse can be heated to raise the temperature if the outside temperature is too low.
- If heaters use fossil fuels such as gas, this produces carbon dioxide and water vapour. The carbon dioxide is a raw material of photosynthesis. The water vapour maintains a moist atmosphere and reduces water loss by transpiration.
- If the plants are grown in a hydroponic culture this provides *exactly* the right balance of mineral ions for the particular crop.

KEY POINT

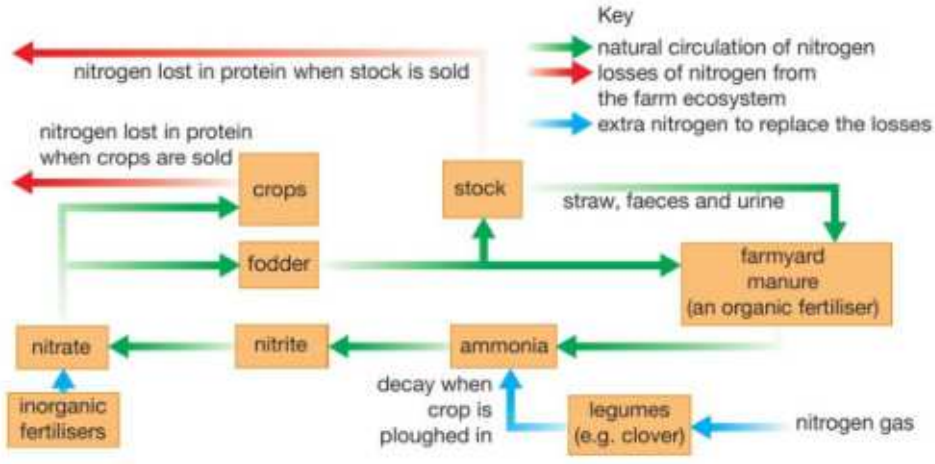
By heating glasshouses to the optimum temperature for photosynthesis, a farmer can maximise his yield. Heating above this temperature is a waste of money as there is no further increase in yield.

CYCLING NUTRIENTS ON A FARM

In Chapter 14 you saw how carbon is cycled in nature. On a farm, the situation is quite different, particularly with regard to the circulation of nitrogen.

Nitrates from the soil supply nitrogen that is needed to make proteins in plants. Some of these plants are crops that will be sold; others are used as food for the stock animals (fodder). When the crops are sold, the nitrogen in the proteins goes with them and is lost from the farm ecosystem. Similarly, when livestock is sold, the nitrogen in their proteins (gained from the fodder) goes with them and is lost from the farm ecosystem. To replace the lost nitrogen, a farmer usually adds some kind of fertiliser. The amount of fertiliser added must be carefully monitored to ensure the maximum growth and yield of the crop – using excess fertiliser wastes money.

Figure 15.5 summarises the circulation of nitrogen on a farm.



▲ Figure 15.5 The nitrogen cycle on a farm.

FERTILISERS INCREASE CROP YIELD

There are two main types of fertilisers – *organic* and *inorganic*. Many organic fertilisers (such as farmyard manure) are made from the faeces of farm animals mixed with straw. Inorganic fertilisers are simply inorganic compounds such as potassium nitrate or ammonium nitrate, carefully formulated to provide a specific amount of nitrate (or some other ion) when applied according to the manufacturer's instructions.

Adding farmyard manure returns some nitrogen to the soil. But, as farmyard manure is made from livestock faeces and indigestible fodder, it can only replace a portion of the lost nitrogen. Most farmers apply inorganic fertilisers to replace the nitrates and other mineral ions lost. While this can replace *all* the lost ions, it can also lead to pollution problems, which we will discuss later. Inorganic fertilisers do not improve soil structure in the way that organic fertilisers can, because they do not contain any decaying matter that is an essential part of the soil.

Another way to replace lost nitrates is to grow a legume crop (e.g. clover) in a field one year in four. Legumes have **nitrogen-fixing bacteria** in nodules on their roots. These bacteria convert nitrogen gas in the soil air to ammonium ions. Some of this is passed to the plants, which use it to make proteins. At the end of the season, the crop is ploughed back into the soil, and decomposers convert the nitrogen in the proteins to ammonia. This is then oxidised to nitrate by **nitrifying bacteria** and made available for next year's crop.

PEST CONTROL

Pests are organisms that reduce the yield of crop plants or stock animals. The 'yield' of a crop is the amount produced for sale. A pest can harm this in two ways:

- lowering the amount by reducing growth, e.g. by damaging leaves and reducing photosynthesis
- affecting the appearance or quality of a crop, making it unsuitable for sale (Figure 15.6).

DID YOU KNOW?
In Britain, about 30% of the potential maize crop is lost to weeds, insects and fungal diseases (Figure 15.6).



▲ Figure 15.6 Damage to a maize (corn) cob caused by the corn earworm caterpillar.

DID YOU KNOW?
A weed is a plant that is growing where it is not wanted. Weeds can be controlled mechanically or chemically. Mechanical control involves physically removing the weeds. Chemical control uses herbicides.

Any type of organism – plants, animals, bacteria, fungi or protoctists, as well as viruses – can be a pest. Pests can be controlled in a number of ways. Chemicals called **pesticides** can be used to kill them, or their numbers can be reduced by using **biological control** methods.

Pesticides are named according to the type of organism they kill:

- herbicides kill plant pests (they are weedkillers)
- insecticides kill insects
- fungicides kill fungi
- molluscicides kill snails and slugs.

A farmer uses pesticides to kill particular pests and improve the yield from

the crops or livestock. Pests are only a problem when they are present in big enough numbers to cause economic damage – a few whiteflies in a tomato crop are not a problem; the real damage arises when there are millions of them. Whether or not a farmer uses pesticides is largely a decision based on cost. The increase in income due to higher yields must be set against the cost of the pesticides.

PROBLEMS WITH PESTICIDES

DID YOU KNOW?

Cultivating large areas of land with a single crop (a *monoculture*) encourages pests. Monocultures make harvesting the crop easier. But if a pest arrives, it can easily spread through the crop. During the winter the pest can lie dormant in the soil ready to attack next year's crop.

Crop rotation breaks the pest cycle. This is where a different crop is grown each year (Figure 15.7). When over-wintering pests emerge, their preferred crop is no longer there.



▲ Figure 15.7 A three-year crop rotation.

DID YOU KNOW?

DDT is a historical case, but there are problems with many modern pesticides. One recent example involves a class of insecticides called *neonicotinoids* (chemicals similar to nicotine). They have been linked to several serious ecological problems, including honey bee colony collapse disorder (CCD) and loss of birds due to a reduction in insect populations.

One problem with using pesticides is that a pest may develop *resistance* to the chemical. This happens through **natural selection** (see Chapter 19). It makes the existing pesticide useless, so that another must be found. Other problems are to do with the fact that pesticides can cause environmental damage. There are several reasons for this:

- they may be slow to decompose – they are *persistent* in the environment
- they build up in the tissues of organisms – *bioaccumulation*
- they build up and become more concentrated along food chains – *biomagnification*
- they kill other insects that are harmless, as well as helpful species, such as bees.

An ideal pesticide should:

- control the pest effectively
- be biodegradable, so that no toxic products are left in the soil or on crops
- be specific, so that only the pest is killed
- not accumulate in organisms
- be safe to transport, store and apply
- be easy to apply.

We can explain these problems by looking at one well-documented example – the insecticide DDT (dichlorodiphenyltrichloroethane).

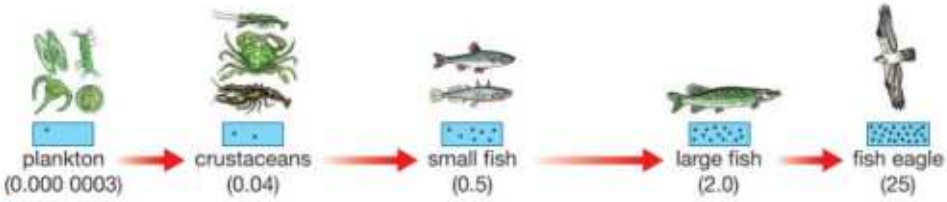
DDT was invented in 1874, and first discovered to be an insecticide in 1939. In World War II it was used with great success to kill malaria carrying mosquitoes and the lice that carried typhus. Its use increased up until the 1960s, when we began to understand its harmful effects. It was banned from general use in the USA in 1972, and worldwide in 2004. Limited use of DDT is still allowed for control of insects that transmit disease, although this is still regarded as controversial.

DDT is a very effective insecticide, so why has it been banned?

- DDT is very persistent, remaining active in the environment for many years. If DDT is sprayed onto a field, around half will still be there ten years later. To make things worse, the missing half won't have degraded to harmless products – some will have broken down to form a similar compound called DDE, which is also a potent insecticide, and some will have spread to other habitats. DDT is carried all around the world by wind, and has been identified in polar ice caps and deserts, thousands of kilometres away from where it was applied.
- By the 1950s, many types of insect began to appear that were resistant to DDT. These insects had developed a genetic **mutation** that prevented them from being killed by the insecticide. While DDT continued to be used, the resistant insects had an advantage over the non-resistant ones. Their numbers increased with every generation since they were able to survive exposure to the pesticide. They reproduced, passing on their resistance genes to their offspring. This is an example of natural selection (see Chapter 19). There are now hundreds of examples of pest species that have

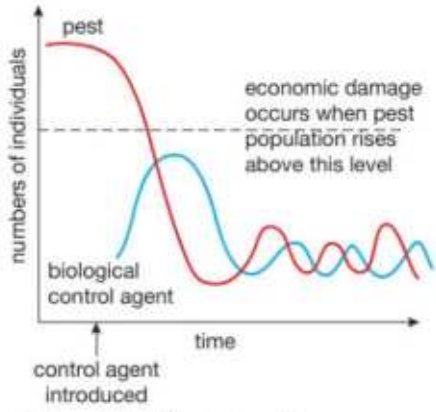
developed resistance to different insecticides.

- DDT doesn't just kill pests. It will kill any type of insect, including harmless ones such as butterflies and useful species such as bees, as well as natural predators such as wasps, which might themselves kill the pest insects. Insecticides damage ecosystems by disrupting food chains.
- DDT is very soluble in fats. When a herbivore feeds on plants that are contaminated with DDT, the insecticide is not broken down or excreted. Instead it becomes concentrated in the fatty tissues of the animal. This is called **bioaccumulation**. When a carnivore eats the herbivore this process is repeated, so that the insecticide builds up in concentration along the food chain. This is known as **biomagnification** (Figure 15.8). The levels at the top of the food chain may be toxic, leading to the death of the top carnivores in the chain. This can disrupt the food web of an ecosystem.



▲ Figure 15.8 Biomagnification of DDT in a food chain

BIOLOGICAL CONTROL



▲ Figure 15.9 Biological control.

Another option that may be used to control pests is biological control. Instead of using a toxic chemical, biological control uses another organism to reduce the numbers of a pest. We have already mentioned whiteflies as pests of tomatoes. One way of controlling them in large glasshouses is to introduce a parasite that will kill the whiteflies. A tiny wasp called *Encarsia* parasitises and kills their larvae, reducing the numbers of adult whitefly.

A problem with biological control is that it never fully gets rid of a pest. If the control organism killed *all* the pests, then it too would die out, as it would have no food supply. Biological control aims to reduce pest numbers to a level where they no longer cause significant economic damage (Figure 15.9).

There are several methods of biological control. Some examples include:

- introducing a natural predator – ladybirds can be used to control the populations of aphids in orange groves
- introducing a herbivore – a moth was introduced from South America to control the prickly pear cactus that was becoming a serious weed in grazing land in Australia
- introducing a parasite – the wasp *Encarsia* is used to control whitefly populations in glasshouse tomato crops
- introducing a pathogenic (disease-causing) microorganism – the myxomatosis virus was deliberately released in Australia to control the rabbit population
- introducing sterile males – these mate with the females but no offspring are produced from these matings, so numbers fall
- using pheromones – these are natural chemicals produced by insects to attract a mate. They are used to attract pests (either males or females) to traps. The pests are then destroyed, reducing the reproductive potential of the population. Male-attracting pheromones are used to control aphids (greenfly) in plum crops.

AIR POLLUTION

One definition of **pollution** is:

> 'Pollution is the contamination of the environment by harmful substances that are produced by the activities of humans'.

Human activities pollute the air with many gases. Some major examples that we will look at in this chapter are carbon dioxide, methane, carbon monoxide and sulfur dioxide.

CARBON DIOXIDE AND GLOBAL WARMING

KEY POINT

In any one year, there is a peak and a trough in the levels of carbon dioxide in the atmosphere

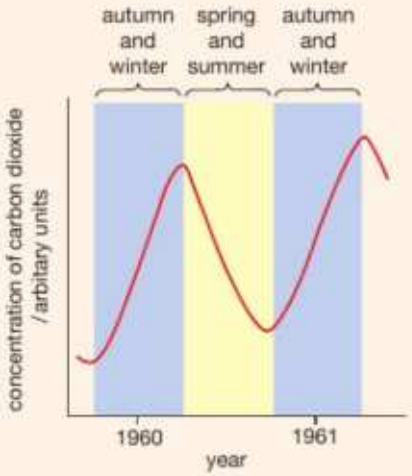
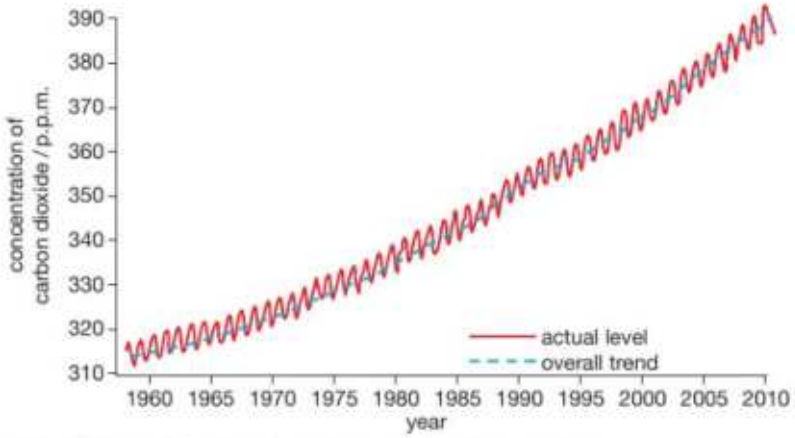


Figure 15.11 Seasonal fluctuations in carbon dioxide levels.

In the autumn and winter, trees lose their leaves. Without leaves they cannot photosynthesise and so do not absorb carbon dioxide. They still respire, which produces carbon dioxide, so in the winter months, they give out carbon dioxide and the level in the atmosphere rises. In the spring and summer, with new leaves and brighter sunlight, the trees photosynthesise faster than they respire. As a result, they absorb more carbon dioxide from the atmosphere than they produce, so the level decreases. However, because there are fewer trees overall, it doesn't quite return to the low level of the previous summer.

The levels of carbon dioxide have been rising for several hundred years. Over the last 100 years alone, the level of carbon dioxide in the atmosphere has increased by nearly 30%. This rise is mainly due to the increased burning of fossil fuels, such as coal, oil and natural gas, as well as petrol and diesel in vehicle engines. It has been made worse by cutting down large areas of tropical rainforest (see later in this chapter). These extensive forests have been called 'the lungs of the Earth' because they absorb such vast quantities of carbon dioxide and produce equally large amounts of oxygen. Extensive deforestation (see below) means that less carbon dioxide is being absorbed. Figure 15.10 shows changes in the level of carbon dioxide in the atmosphere (in parts per million) from 1960 to 2010.



▲ Figure 15.10 Changes in the level of carbon dioxide in the atmosphere.

The increased levels of carbon dioxide and other gases contribute to global warming, or the enhanced greenhouse effect. It is important to understand that the 'normal' greenhouse effect occurs naturally – without it, more heat would be lost into space and the surface temperature of the Earth would be about 30 °C lower than it is today, and life as we know it would be impossible.

Carbon dioxide is one of the 'greenhouse gases' that are present in the Earth's upper atmosphere. Other greenhouse gases include water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Most greenhouse gases occur naturally, while some (like CFCs) are only produced by human activities.

The 'normal' greenhouse effect is shown in Figure 15.12.

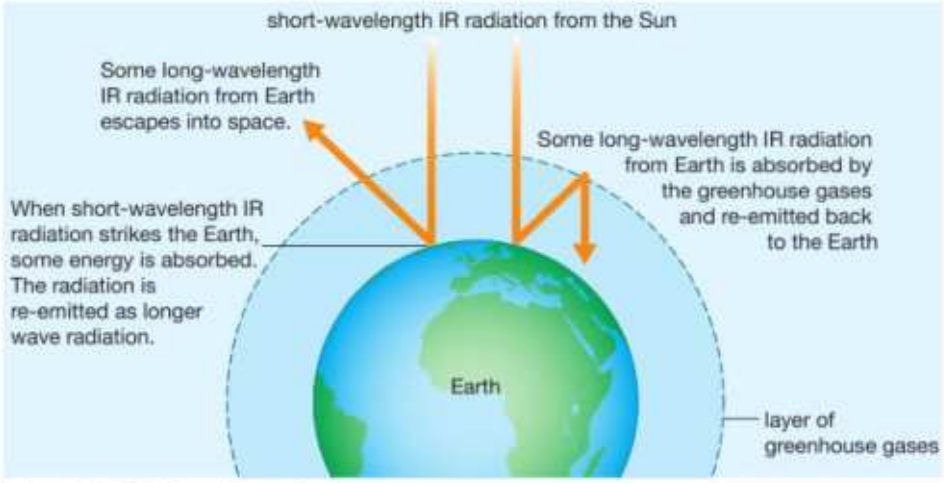


Figure 15.12 The Greenhouse effect

Short-wavelength infrared (IR) radiation from the Sun reaches the Earth. Some is absorbed by the Earth's surface and emitted again as longer-wavelength IR radiation. The greenhouse gases absorb and then re-emit some of this long-wavelength IR radiation, which would otherwise escape into space. This then heats up the surface of the Earth.

DID YOU KNOW?

Chlorofluorocarbons or CFCs are complex organic molecules containing carbon, chlorine and fluorine. They were once widely used in fridges, spray cans and as solvents, as well as in making materials such as foam packaging. Their use was banned or phased out in many countries in 1987, when they were found to be damaging the ozone layer in the upper atmosphere. (This layer protects living organisms by absorbing harmful ultraviolet radiation from the Sun.)

The problem is that human activities are polluting the atmosphere with *extra* greenhouse gases such as carbon dioxide. This is thought to be causing a rise in the Earth's surface temperature – the enhanced greenhouse effect, or global warming.

A rise in the Earth's temperature of only a few degrees would have many effects.

- Polar ice caps would melt and sea levels would rise.
- A change in the major ocean currents would result in warm water flowing into previously cooler areas.
- A change in global rainfall patterns could result. With a rise in temperature, there will be more evaporation from the surface of the sea, leading to more water vapour in the atmosphere and more rainfall in some areas. Other areas could experience a decrease in rainfall. Long-term climate change could occur.
- It could change the nature of many ecosystems. If species could not migrate quickly enough to a new, appropriate habitat, or adapt quickly enough to the changed conditions in their original habitat, they could become extinct.
- Changes in farming practices would be necessary as some pests became more abundant. Higher temperatures might allow some pests to complete their life cycles more quickly.

DID YOU KNOW?

Infrared radiation is radiated heat. The heat you can feel from an electric fire is IR radiation.

METHANE

Methane (CH_4) is an organic gas. It is produced when microorganisms ferment larger organic molecules to release energy. The most significant sources of methane are:

- **decomposition** of waste buried in the ground ('landfill sites'), by microorganisms
- fermentation by microorganisms in the rumen (stomach) of cattle and other ruminants
- fermentation by bacteria in rice fields.

DID YOU KNOW?
Cattle can produce up to 40 dm^3 of methane per animal per hour.

Methane is a greenhouse gas, with effects similar to carbon dioxide. Although there is less methane in the atmosphere than carbon dioxide, each molecule has a much bigger greenhouse effect.

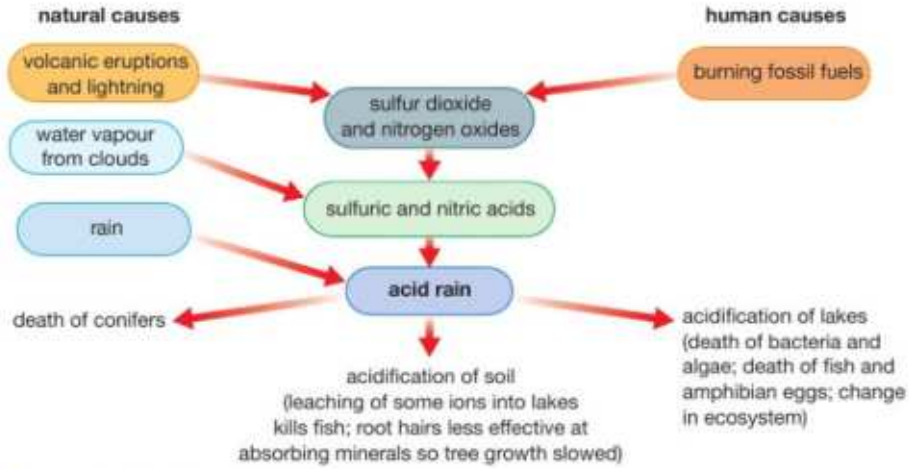
CARBON MONOXIDE

When substances containing carbon are burned in a limited supply of oxygen, carbon monoxide (CO) is formed. This happens when petrol and diesel are burned in vehicle engines. Exhaust gases contain significant amounts of carbon monoxide. It is a dangerous pollutant as it is colourless, odourless and tasteless and can be fatal. Haemoglobin binds more strongly with carbon monoxide than with oxygen. If a person inhales carbon monoxide for a period of time, more and more haemoglobin becomes bound to carbon monoxide and so cannot bind with oxygen. The person may lose consciousness and eventually die, as a result of a lack of oxygen reaching the cells, so that organs such as the heart and brain stop working.

KEY POINT
In many countries there are now strict laws controlling the permitted levels of carbon monoxide in the exhaust gases produced by newly designed engines.

SULFUR DIOXIDE

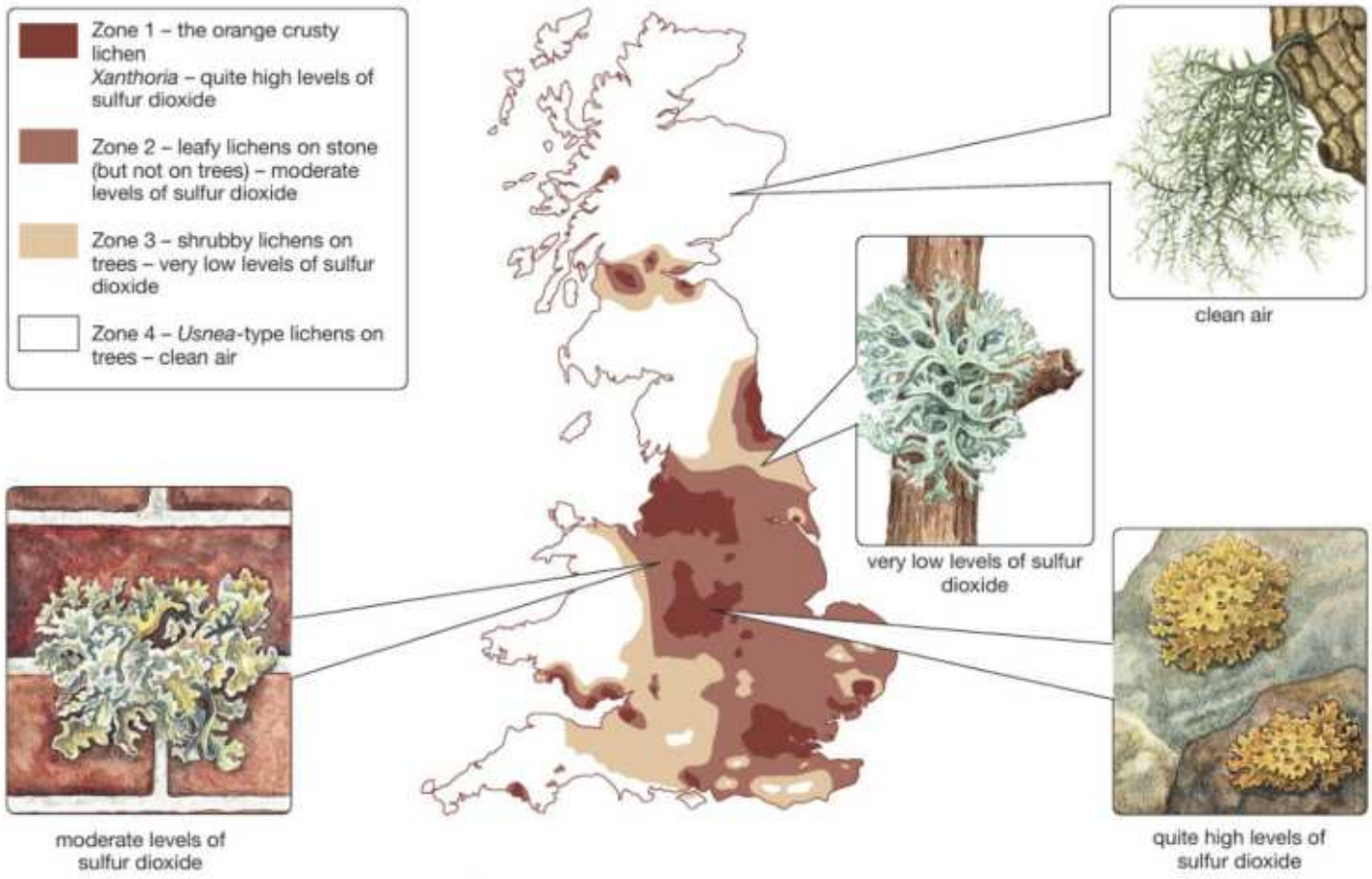
Sulfur dioxide (SO_2) is an important air pollutant. It is formed when fossil fuels are burned, and combines with water droplets in the air. It can be carried hundreds of miles in the atmosphere before falling as **acid rain**. Rain normally has a pH of about 5.5 – it is slightly acidic due to the carbon dioxide dissolved in it. Both sulfur dioxide and nitrogen oxides dissolve in rainwater to form a mixture of acids, including sulfuric acid and nitric acid. As a result, the rainwater is more acidic with a much lower pH than normal rain (Figure 15.13).



▲ Figure 15.13 The formation of acid rain and its effects on living organisms.

Lichens are small moss-like organisms. Some lichens are more tolerant of sulfur dioxide than others. In some countries, patterns of lichen growth can be used

to monitor the level of pollution by sulfur dioxide. The different lichens are called *indicator species* as they 'indicate' different levels of sulfur dioxide pollution.



▲ Figure 15.14 Lichens are sensitive to pollution levels.

The map in Figure 15.14 shows zones in Britain where different types of lichen are found.

WATER POLLUTION

Two major pollutants of freshwater are sewage and minerals from fertiliser.

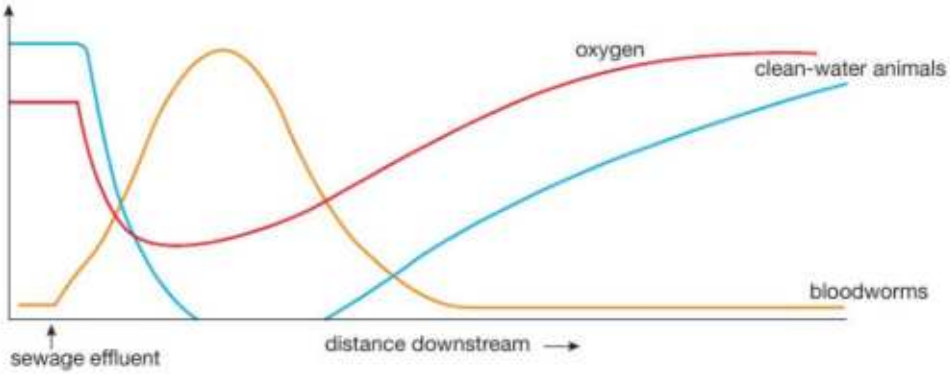
POLLUTION OF WATER BY SEWAGE

Sewage is wet waste from houses, factories and farms. In developed countries where large-scale sewage treatment takes place, industrial and agricultural sewage is usually dealt with separately from household sewage. Household sewage consists of wastewater from kitchens and bathrooms and contains human urine and faeces, as well as dissolved organic and inorganic chemicals such as soaps and detergents. It is carried away in pipes called sewers, to be treated before it enters waterways such as rivers or the sea.

If sewage is discharged untreated into waterways, it produces two major problems:

- Aerobic bacteria in the water polluted by the sewage use up the dissolved oxygen in the water as they break down the organic materials. This reduction in the level of oxygen kills larger animals such as freshwater insects and fish.
- Untreated sewage contains pathogenic bacteria, which are a danger to human health.

Where untreated or 'raw' sewage enters a river, the level of oxygen in the water becomes very low as the aerobic bacteria and other microorganisms from the sewage decompose the organic matter. Only species that are adapted to live in low-oxygen conditions, such as anaerobic bacteria, can survive. As the water moves away from the outlet, it becomes oxygenated again as it mixes with clean water and absorbs oxygen from the air. The increase in dissolved oxygen levels allows more clean-water species to survive. Figure 15.15 shows the changes in oxygen content, numbers of clean-water animals, and numbers of polluted-water animals downstream from a sewage outlet.



▲ Figure 15.15 Changes in oxygen levels and types of organism living downstream from a sewage outlet into a river.

The aim of sewage treatment is to remove solid and suspended organic matter and pathogenic microorganisms, so that cleaner waste can be discharged into waterways.

As with air pollution by sulfur dioxide, the level of pollution by organic material can be monitored by the presence or absence of indicator species. Figure 15.16 shows some of these.



▲ Figure 15.16 Some freshwater animals will only live in very clean water, while others can survive in very polluted areas.

EUTROPHICATION

Eutrophication comes from a Greek word, meaning 'well-fed'. It refers to a situation where large amounts of nutrients enter a body of water, such as a river, lake or even the sea. The nutrients in question are inorganic mineral ions, usually nitrates or phosphates. Pollution by these minerals can have very harmful effects on an aquatic ecosystem.

There are two main sources of excess minerals:

- from untreated or treated sewage
- from artificial nitrate or phosphate fertilisers.

Eutrophication is often caused by the use of artificial fertiliser. Streams and rivers that run through agricultural land that have been treated with fertiliser can contain high concentrations of nitrate and phosphate. This is because nitrate is very soluble in water, and is easily washed out of the soil by rain, a process known as **leaching**. This is less of a problem with phosphate fertiliser, but phosphate is also washed into waterways by surface run-off of water.

The excess mineral ions stimulate the growth of all plants in the river or lake, but this is usually seen first as a rapid growth of algae, called an **algal bloom**. The algae can increase in numbers so rapidly that they form a thick scum on the surface of the water (Figure 15.17).



Figure 15.17 An algal bloom caused by fertiliser

The algae soon start to die, and are decomposed by aerobic bacteria in the water. Because the bacteria respire aerobically, they use up the oxygen in the water. In addition, the algae block the light from reaching other rooted plants, further decreasing the oxygen produced by photosynthesis. The low oxygen levels can result in fish and other aerobic animals dying. In severe cases, the water becomes *anoxic* (containing very little oxygen) and smelly from gases like hydrogen sulfide and methane from the bacteria. By this stage only anaerobic bacteria can survive.

Rapid eutrophication is less likely when farmers use organic fertiliser (manure). The organic nitrogen-containing compounds in manure are less soluble and so are leached less quickly from the soil.

REMINDER

The sequence of events following eutrophication is:

increase in mineral ions
↓
algal bloom
↓
death of algae
↓
decomposition by aerobic bacteria
↓
bacteria use up oxygen
↓
fish and other animals die

CHAPTER QUESTIONS

More questions on human influences on the environment can be found at the end of Unit 4 on page 191.

SKILLS CRITICAL THINKING

1 Which of the following is a desirable property for a pesticide?

A It kills all insects

B It does not show bioaccumulation

C It is persistent in the environment

D It is not biodegradable

2 The following gases are found in atmospheric air:

1. nitrogen
2. methane
3. carbon dioxide
4. water vapour

Which of these is/are *not* a greenhouse gas?

A 1 only

B 1 and 4

C 2 and 3

D 2 and 4

3 In a lake affected by eutrophication, which of the following causes the death of aquatic plants?

A Poisoning by excess minerals

B Lack of oxygen in the water

C Lack of light reaching the plants

D Lack of carbon dioxide in the water

SKILLS REASONING

4 Why are humans having much more of an impact on their environment now than they did 500 years ago?

SKILLS ANALYSIS

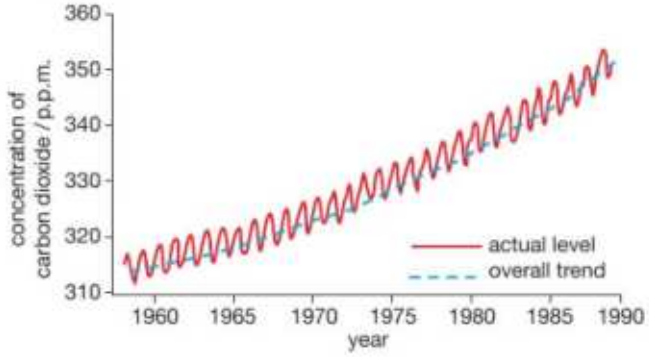
5 The graph shows the changing concentrations of carbon dioxide at Mauna Loa, Hawaii over a number of years.

SKILLS REASONING

a Describe the overall trend shown by the graph.

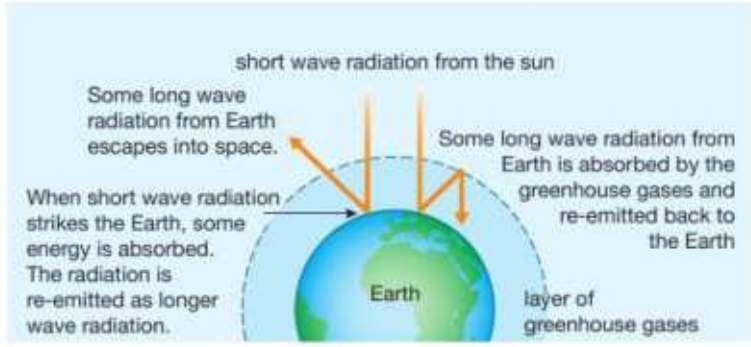
b Explain the trend described in a).

c In any one year, the level of atmospheric carbon dioxide shows a peak and a trough. Explain why.



SKILLS REASONING

6 The diagram shows how the greenhouse effect is thought to operate.

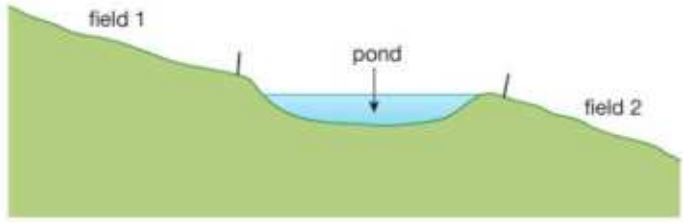


a Name two greenhouse gases.

b Explain one benefit to the Earth of the greenhouse effect.

c Suggest why global warming may lead to malaria becoming more common in Europe.

7 The diagram shows the profile of the ground on a farm either side of a pond.



The farmer applied nitrate fertiliser to the two fields in alternate years. When he applied the fertiliser to Field 1, the pond often developed an algal bloom. This did not happen when fertiliser was applied to Field 2.

a Explain why an algal bloom developed when he applied the fertiliser to Field 1.

b Explain why no algal bloom developed when he applies the fertiliser to Field 2.

c Suggest why the algal bloom is greater in hot weather.

8 Some untreated sewage was accidentally discharged into a small river. A short time afterwards, a number of dead fish are seen downstream of the point of discharge. Explain, as fully as you can, how the discharge might have led to the death of the fish.

9 Some farmers use pesticides and fertilisers to improve crop yields. Those practising 'organic' farming techniques do not use any artificial products.

a Describe how the use of pesticides and fertilisers can improve crop yields.

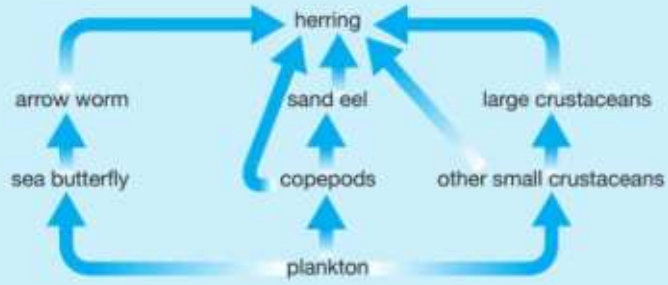
SKILLS CRITICAL THINKING

b Explain how organic farmers can maintain fertile soil and keep their crops free of pests.

UNIT QUESTIONS

SKILLS INTERPRETATION

1 The diagram shows a simplified food web of a fish, the herring.



a i Write out a food chain from the above food web containing four organisms. **(1)**

SKILLS ANALYSIS

ii From your food chain, name the primary consumer and secondary consumer. **(2)**

iii Name one organism in the web that is both a secondary consumer and a tertiary consumer. Explain your answer. **(2)**

b The amount of energy in each trophic level has been provided for the following food chain. The units are kJ per m^2 per year

plankton (8869) → copepod (892) → herring (91)

SKILLS INTERPRETATION

i Sketch a pyramid of energy for this food chain. **(1)**

SKILLS PROBLEM SOLVING

ii Calculate the percentage of energy entering the plankton that passes to the copepod. **(2)**

iii Calculate the percentage of energy entering the copepod that passes to the herring. **(2)**

iv Calculate the amount of energy that enters the food chain per year if the plankton use 0.1% of the available energy. **(2)**

SKILLS REASONING

v Explain two ways in which energy is lost in the transfer from the copepod to the herring. **(2)**

(Total 14 marks)

SKILLS INTERPRETATION 7th

2 A farmer added nitrate fertiliser to his wheat crop to try to increase yield. The table below shows the wheat yield when he added different amounts of nitrate fertiliser.

Fertiliser added / kg per hectare	Wheat yield / tonnes per hectare
0	15
50	18
100	22
150	31
200	30
250	31

a Use the information in the table to draw a line graph showing the effects of fertiliser on wheat yield. **(4)**

SKILLS PROBLEM SOLVING 6th

b What amount of fertiliser would you advise the farmer to use on his wheat crop? Explain your answer. **(3)**

SKILLS REASONING 5th

c Why is nitrate needed to help plants grow? **(1)**

7th

d Excess nitrate can be washed into rivers. Explain the effects that this could have on the river ecosystem. **(5)**

(Total 13 marks)

SKILLS ANALYSIS, REASONING

3 Insecticides are used by farmers to control the populations of insect pests. New insecticides are continually being developed.

a A new insecticide was trialled over three years to test its effectiveness in controlling an insect pest of potato plants. Three different concentrations of the insecticide were tested. Some results are shown in the table.

Concentration	Percentage of insect pest killed each year of insecticide		
	Year 1	Year 2	Year 3
1 (weakest)	95	72	18
2 (intermediate)	98	90	43
3 (strongest)	99	91	47

i Describe, and suggest an explanation for, the change in the effectiveness of the insecticide over the three years. **(3)**

6th

ii Which concentration would a farmer be most likely to choose to apply to potato crops? Explain your answer. **(3)**

b The trials also showed that there was no significant bioaccumulation of the insecticide.

SKILLS CRITICAL THINKING 5th 6th

i What is bioaccumulation? **(1)**

ii Give an example of bioaccumulation of an insecticide and describe its consequences. **(2)**

iii Explain why it is particularly important that there is no bioaccumulation of this insecticide. **(1)**

(Total 10 marks)

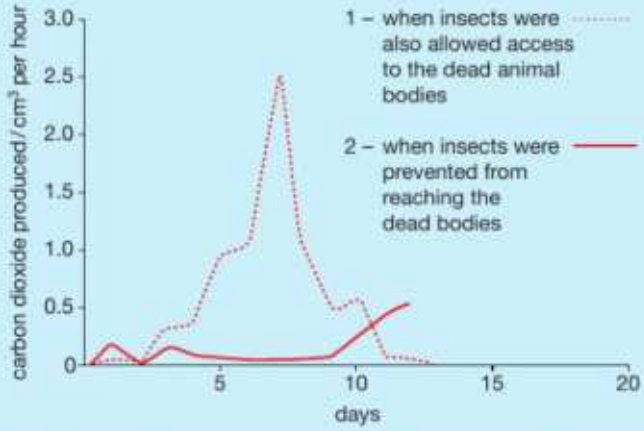
8th **4** Carbon is passed through ecosystems by the actions of plants, animals and decomposers, in the carbon cycle. Humans influence the carbon cycle more than other animals.

a Explain the importance of plants in the carbon cycle. **(2)**

7th **b** Describe two human activities that have significant effects on the world carbon cycle. **(2)**

SKILLS ANALYSIS, REASONING

c The graph shows the activity of decomposers acting on the bodies of dead animals under different conditions.



i Explain why carbon dioxide production was used as a measure of the activity of the decomposers. **(2)**

ii Describe and explain the changes in decomposer activity when insects were also allowed access to the dead bodies (curve 1) **(3)**

iii Describe two differences between curves (1) and (2). Suggest an explanation for the differences you describe. **(4)**

(Total 13 marks)

SKILLS REASONING 6th **5** In natural ecosystems, there is competition between members of the same species as well as between different species.

a Explain how competition between members of the same species helps to control population growth. **(3)**

b Crop plants must often compete with weeds for resources. Farmers often control weeds by spraying herbicides (weedkillers).

SKILLS CRITICAL THINKING

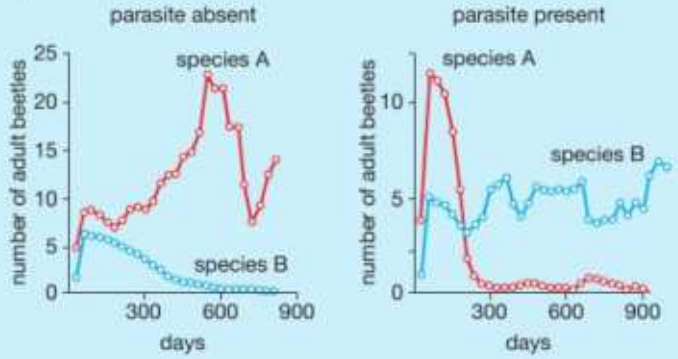
i Name two factors that the crop plants and weeds may compete for and explain the importance of each. **(4)**

SKILLS REASONING 7th

ii Farmers usually prefer to spray herbicides on weeds early in the growing season. Suggest why. **(2)**

SKILLS ANALYSIS

c Two species of the flour beetle, *Tribolium*, compete with each other for flour. Both are parasitised by a protozoan. The graphs show the changes in numbers of the two species over 900 days when the parasite is absent and when it is present.



i Which species is the most successful when the parasite is absent? Justify your answer. **(2)**

ii What is the effect of the parasite on the relative success of the two beetles? Suggest an explanation for your answer. **(4)**

(Total 15 marks)

SKILLS PROBLEM SOLVING

6 The table gives information about the pollutants produced in extracting aluminium from its ore (bauxite) and in recycling aluminium.

Pollutants	Amount / g per kg aluminium produced	
air	extraction from bauxite	recycling aluminium
sulfur dioxide	88600	886
nitrogen oxides	139000	6760
carbon monoxide	34600	2440
Water		
dissolved solids	18600	575
suspended solids	1600	175

a Calculate the percentage reduction in sulfur dioxide pollution by recycling aluminium. **(2)**

SKILLS REASONING

b Explain how extraction of aluminium from bauxite may contribute to the acidification of water hundreds of miles from the factory where the aluminium is extracted. **(3)**

c Suggest two reasons why there may be little plant life in water near an extraction. **(4)**

(Total 9 marks)

SKILLS INTERPRETATION 7 marks

7 Rust fungi infect the leaves of many crop plants.

a Explain two ways in which an infection by rust fungi can reduce crop yield. **(2)**

b Infections of rust fungi can be controlled by spraying the crops with a fungicide. In an investigation into the effectiveness of this method of control, a field of wheat was divided into two plots. As soon as the first signs of infection appeared, one plot was sprayed with fungicide. The other plot was left unsprayed.

The relative amount of infection in the two plots was monitored over 50 days. The table shows the results of the investigation.

Day	Relative amount of infection / arbitrary units	
	Unsprayed (control)	Sprayed plants
0	0	3
10	17	8
20	32	10
30	48	15
40	62	17
50	65	18

SKILLS ANALYSIS 6 marks

i Plot a line graph of these data. **(5)**

ii From your graph, find the relative infection of sprayed and unsprayed plants on day 24. **(2)**

SKILLS EXECUTIVE FUNCTION

iii Explain why it is necessary to have a control group. **(2)**

SKILLS ANALYSIS

iv The investigation was repeated every year for five years. Each year seeds were kept for planting the following year. On day 30 in Year 5, the relative amounts of infection were 46 (unsprayed) and 38 (sprayed). Compare these results with Year 1 and suggest an explanation for the difference. **(3)**

(Total 14 marks)

CHROMOSOMES, GENES AND DNA 197 | CELL DIVISION 202 | GENES AND INHERITANCE 211
NATURAL SELECTION, EVOLUTION AND SELECTIVE BREEDING 222

BIOLOGY UNIT 5 VARIATION AND SELECTION

The genetic code is contained within a chemical in the nucleus of the cell, called DNA. DNA is organised into units called genes. The discovery of the structure of DNA in 1953 was the beginning of a new discipline called molecular biology. Molecular biology looks at how the genetic code in the DNA affects the function of the cell. Molecular biology is closely linked with genetics, which concerns the visible effects of the genes on living organisms . This Unit starts with a look at how DNA forms the genetic code, and how it is passed from cell to cell when a cell divides. Chapter 18 deals with genetics – how the DNA shows itself in organisms. Chapter 19 describes the theory that underpins all of biology – Darwin's theory of evolution by natural selection and the principles of selective breeding.



16 CHROMOSOMES, GENES AND DNA

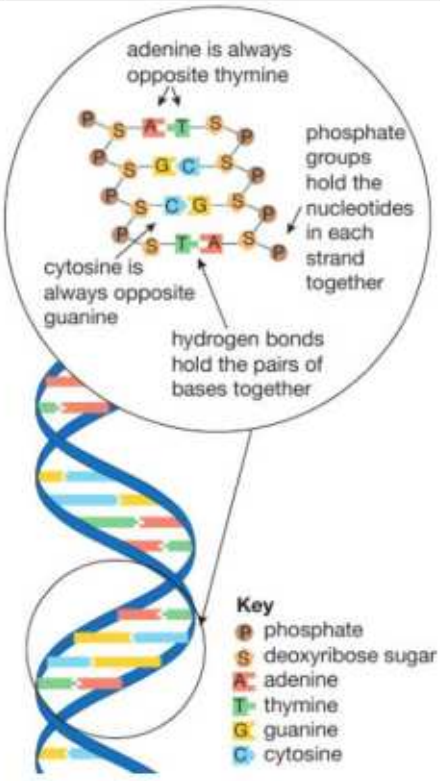
This chapter looks at the structure and organisation of genetic material, namely chromosomes, genes and DNA.

LEARNING OBJECTIVES

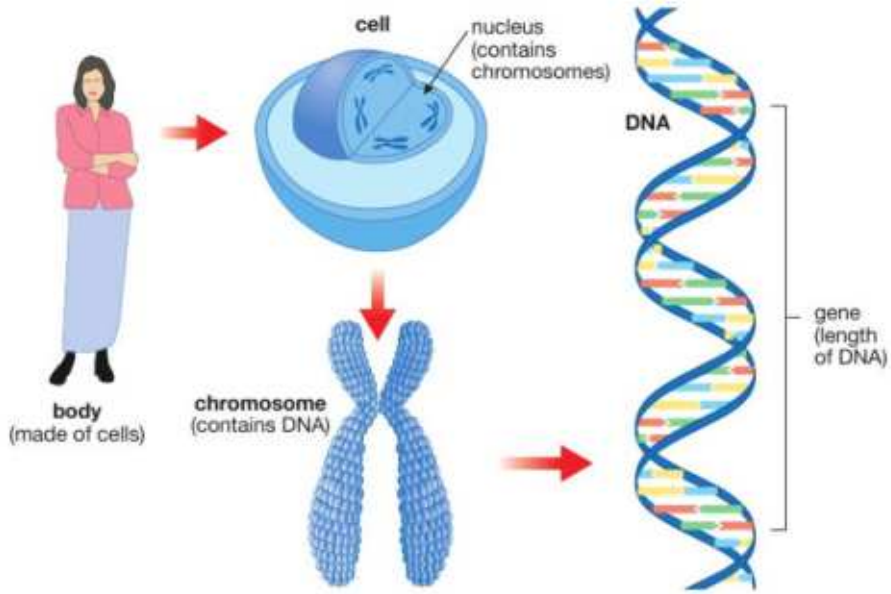
- Understand that the nucleus of a cell contains chromosomes on which genes are located
- Understand that a gene is a section of a molecule of DNA that codes for a specific protein
- Understand that mutation is a rare, random change in genetic material that can be inherited
- Know that in human cells the diploid number of chromosomes is 46 and the haploid number is 23
- Understand that the genome is the entire DNA of an organism
- Understand how genes exist in alternative forms called alleles, which give rise to different inherited characteristics

DID YOU KNOW?

DNA is short for **deoxyribonucleic acid**. It gets the 'deoxyribo' part of its name from the sugar in the DNA molecule – deoxyribose, a sugar containing five carbon atoms.



▲ Figure 16.2 Part of a molecule of DNA.



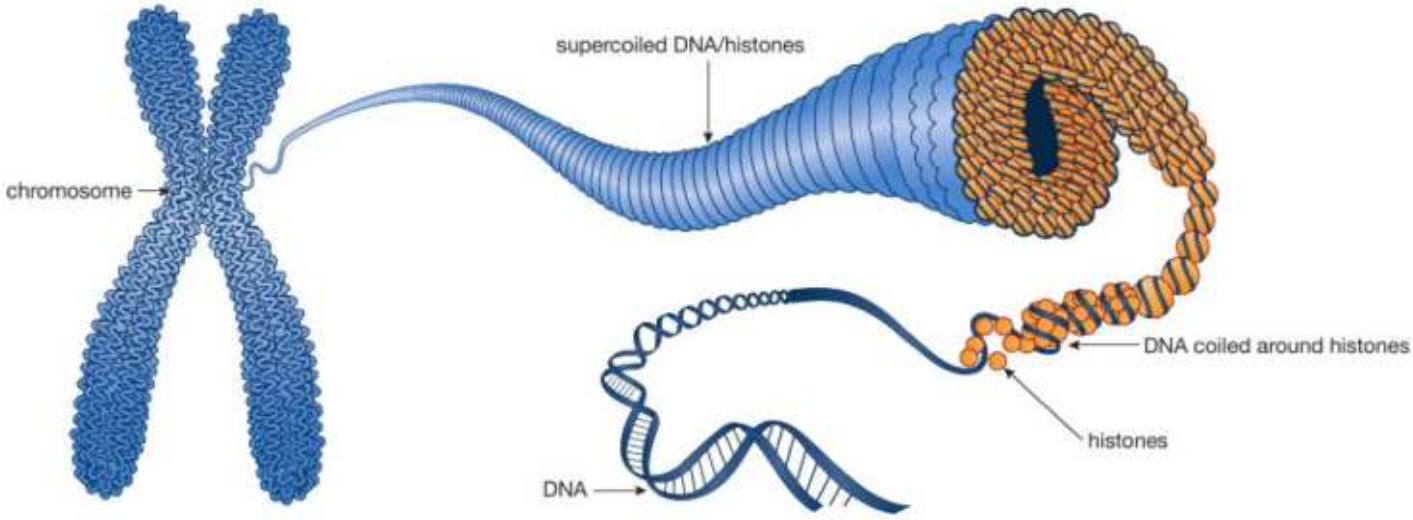
▲ Figure 16.1 Our genetic make-up

The chemical that is the basis of inheritance in nearly all organisms is **DNA**. DNA consists of two strands looking like a twisted ladder - the famous 'double helix'. The 'sides' of the ladder are made of alternating sugar and phosphate groups. The 'rungs' of the ladder are made of pairs of nitrogen-containing groups called bases (Figure 16.2). There are four bases called adenine, thymine, cytosine and guanine. The base adenine always pairs with thymine, and cytosine with guanine. These are called complementary base pairs. DNA is usually found in the nucleus of a cell, in the **chromosomes** (Figure 16.1). A small section of DNA that determines a particular feature is called a **gene**. Genes determine features by instructing cells to produce particular proteins which then lead to the development of the feature. So a gene can also be described as a section of DNA that codes for a particular protein.

DNA can replicate (make an exact copy of) itself. When a cell divides by mitosis (see Chapter 17), each new cell receives exactly the same type and amount of DNA. The cells formed are *genetically identical*.

THE STRUCTURE OF CHROMOSOMES

Each chromosome contains one double-stranded DNA molecule. The DNA is folded and coiled so that it can be packed into a small space. The DNA is coiled around proteins called **histones** (Figure 16.3).

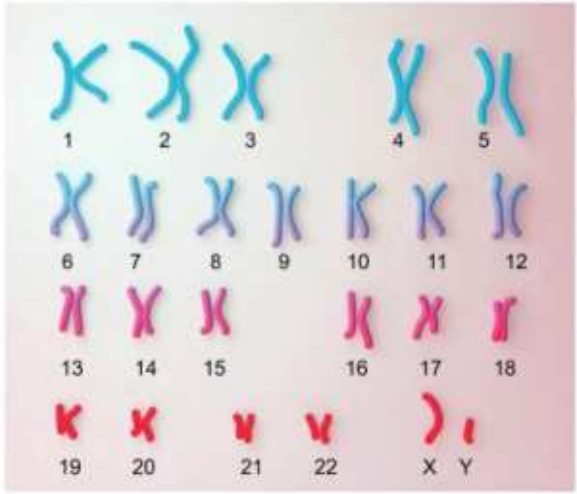


▲ Figure 16.3 The structure of a chromosome

Because a chromosome contains a particular DNA molecule, it will also contain the genes that make up that DNA molecule. Another chromosome will contain a different DNA molecule, and so will contain different genes.

HOW MANY CHROMOSOMES?

Nearly all human cells contain 46 chromosomes. The photographs in Figure 16.4 show the 46 chromosomes from the body cells of a human male.



▲ Figure 16.4 A man's chromosomes. One of each of the 22 homologous pairs are shown, along with the X and Y sex chromosomes. A woman's chromosomes are the same, except that she has two X chromosomes. A picture of all the chromosomes in a cell is called a karyotype.

REMINDER

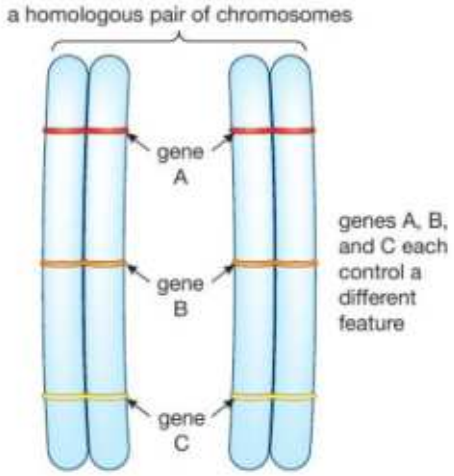
Red blood cells have no nucleus and therefore no chromosomes. (The lack of a nucleus means there is more room for carrying oxygen.)

KEY POINT

The X and the Y chromosomes are the **sex chromosomes**. They determine whether a person is male or female (see Chapter 18).

The chromosomes are not arranged like this in the cell. The original photograph has been cut up and chromosomes of the same size and shape 'paired up'. The cell from the male has 22 pairs of chromosomes and two that do not form a pair – the X and Y chromosomes. A body cell from a female has 23 matching pairs including a pair of X chromosomes.

Pairs of matching chromosomes are called **homologous pairs**. They carry genes for the same features, and these genes are arranged at the same positions and sequence along the chromosome (Figure 16.5). Cells with chromosomes in pairs like this are **diploid** cells.



▲ Figure 16.5 Both chromosomes in a homologous pair have the same sequence of genes.

Not all human cells have 46 chromosomes. Red blood cells have no nucleus and so have none. Sex cells have only 23 – just half the number of other cells. They are formed by a cell division called **meiosis** (see Chapter 17). Each cell formed has one chromosome from each homologous pair, and one of the sex chromosomes. Cells with only half the normal diploid number of chromosomes, and therefore only half the DNA content of other cells, are **haploid** cells.

When two gametes fuse in **fertilisation**, the two nuclei join to form a single diploid cell (a **zygote**). This cell has, once again, all its chromosomes in homologous pairs and two copies of every gene. It has the normal DNA content.

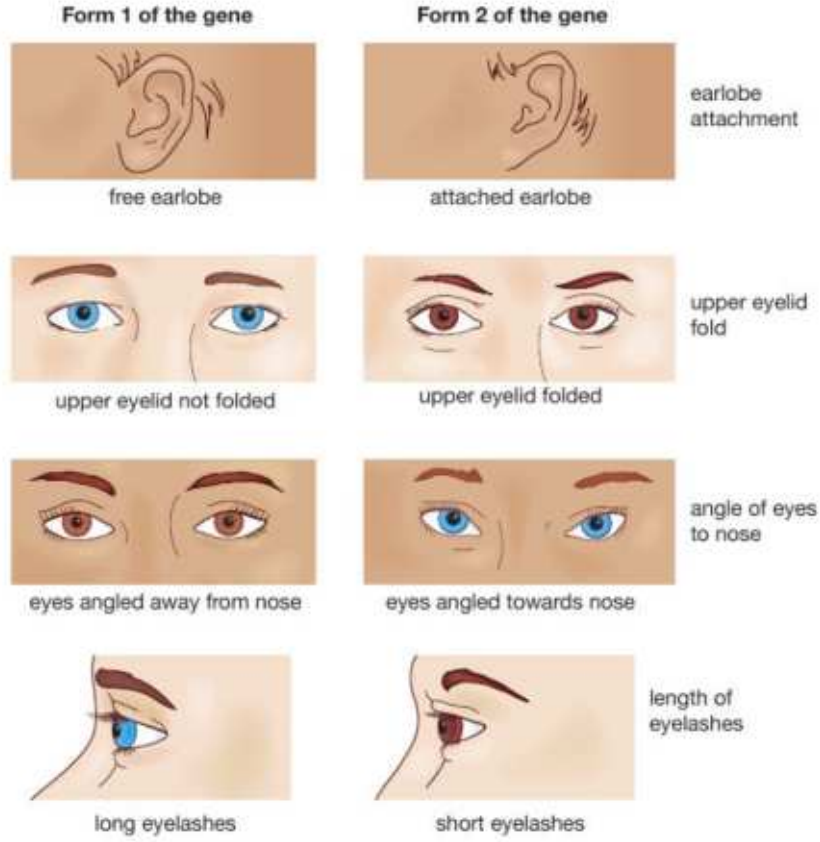
HOW MANY GENES?

The entire DNA of an organism (the amount present in a diploid cell) is known as its **genome**. The human genome is made up of about 3.2 billion **base** pairs. One of the surprise discoveries of modern molecular biology is that only a small fraction of the genome consists of protein-coding genes. For example, the human genome contains about 20 000-25 000 genes coding for proteins, which is only about 1.5% of the total DNA. The rest have other functions, or functions yet to be discovered! (See the 'Looking ahead' feature at the end of this chapter.)

GENES AND ALLELES

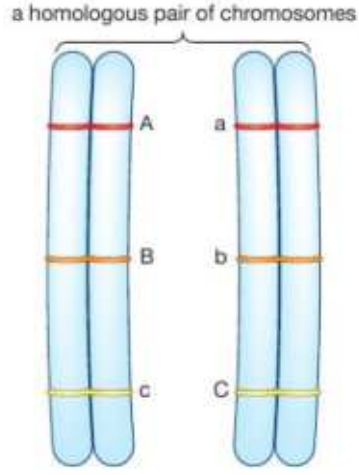
Genes are sections of DNA that control the production of proteins in a cell. Each protein contributes towards a particular body feature. Sometimes the feature is visible, such as eye colour or skin pigmentation. Sometimes the feature is not visible, such as the type of haemoglobin in red blood cells or the type of blood group antigen on the red blood cells.

Some genes have more than one form. For example, the genes controlling several facial features have alternative forms, which result in alternative forms of the feature (Figure 16.6).



▲ Figure 16.6 The alternate forms of four facial features

The gene for earlobe attachment has the forms 'attached earlobe' and 'free earlobe'. These different forms of the gene are called **alleles**. Homologous chromosomes carry genes for the same features in the same sequence, but the alleles of the genes may not be the same (Figure 16.7). The DNA in the two chromosomes is not quite identical.



▲ Figure 16.7 A and a, B and b, and C and c are different alleles of the same gene. They control the same feature but code for different expressions of that feature.

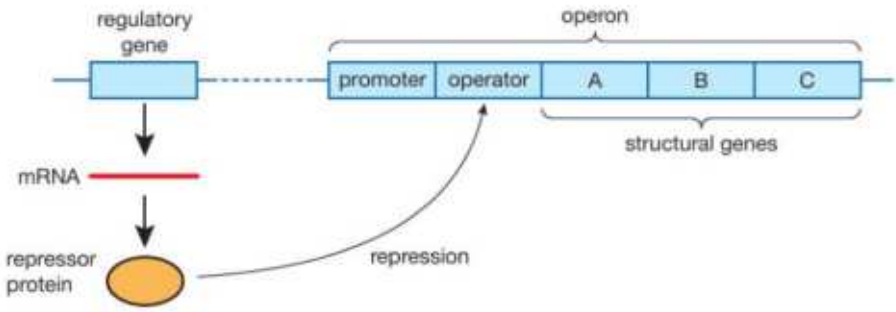
Each cell with two copies of a chromosome also has two copies of the genes on those chromosomes. Suppose that, for the gene controlling earlobe attachment, a person has one allele for attached earlobes and one for free earlobes. What happens? Is one ear free and the other attached? Are they

both partly attached? Neither. In this case, both earlobes are free. The 'free' allele is **dominant.** This means that it will show its effect, whether or not the allele for 'attached' is present. The allele for 'attached' is called **recessive.** The recessive allele will only show up in the appearance of the person if there is no dominant allele present. You will find out more about how genes work in Chapter 18.

LOOKING AHEAD – REGULATING GENES

You have seen how 'normal' gene coding for proteins (known as structural genes) make up only 1.5% of the genome. Some of the rest of the genome is DNA that regulates the action of the structural genes, switching them on and off. One way this happens is in regions of the DNA called operons.

An operon is a group of structural genes headed by a non-coding length of DNA called an operator, along with another sequence of DNA called a promoter. The promoter starts **transcription** by binding to an enzyme called RNA polymerase. Close to the promoter is a regulatory gene, which codes for a protein called a repressor. The repressor can bind with the operator, preventing the promoter from binding with RNA polymerase, and stopping transcription (Figure 16.8).



▲ Figure 16.8 An operon is a group of structural genes linked to an operator and a promoter. It is under the control of a regulatory gene.

The structural genes are in groups because they are related – e.g. they code for different enzymes in a metabolic pathway. Operons were first discovered in bacteria. At first we thought they only existed in prokaryotes, but molecular biologists have now found them in eukaryotic cells too.

CHAPTER QUESTIONS

More questions on DNA can be found at the end of Unit 5 on page 234.

SKILLS CRITICAL THINKING

1 How many chromosomes are there in the body cells of a man?

A 23 pairs + XX
B 23 pairs + XY
C 22 pairs + XX
D 22 pairs + XY

2 a What is:

i a gene
ii an allele?

b Describe the structure of a chromosome.

c How are the chromosomes in a woman's skin cells:

i similar to
ii different from those in a man's skin cells?

17 CELL DIVISION

Growth and reproduction are two characteristics of living things. Both involve cell division, which is the subject of this chapter.

LEARNING OBJECTIVES

- Understand how division of a diploid cell by mitosis produces two cells that contain identical sets of chromosomes
- Understand that mitosis occurs during growth, repair, cloning and asexual reproduction
- Understand how division of a cell by meiosis produces four cells, each with half the number of chromosomes, and that this results in the formation of genetically different haploid gametes
- Understand how random fertilisation produces genetic variation of offspring
- Understand that variation within a species can be genetic, environmental or a combination of both

In most parts of the body, cells need to divide so that organisms can grow and replace worn out or damaged cells. The cells that are produced in this type of cell division should be exactly the same as the cells they are replacing. This is the most common form of cell division.

Only in the sex organs is cell division different. Here, some cells divide to produce gametes (sex cells), which contain only half the original number of chromosomes. This is so that when male and female gametes fuse together (fertilisation) the resulting cell (called a **zygote**) will contain the full set of chromosomes and can then divide and grow into a new individual.

Human body cells are **diploid** – they have 46 chromosomes in 23 homologous pairs. The gametes, with 23 chromosomes (one copy of each homologous chromosome), are **haploid** cells.

There are two kind of cell division: **mitosis** and **meiosis**. When cells divide by mitosis, two cells are formed. These have the same number and type of chromosomes as the original cell. Mitosis forms all the cells in our bodies except the gametes.

When cells divide by meiosis, four cells are formed. These have only half the number of chromosomes of the original cell. Meiosis forms gametes

KEY POINT

Meiosis is sometimes called a *reduction division*. This is because it produces cells with only half the number of chromosomes of the original cell.

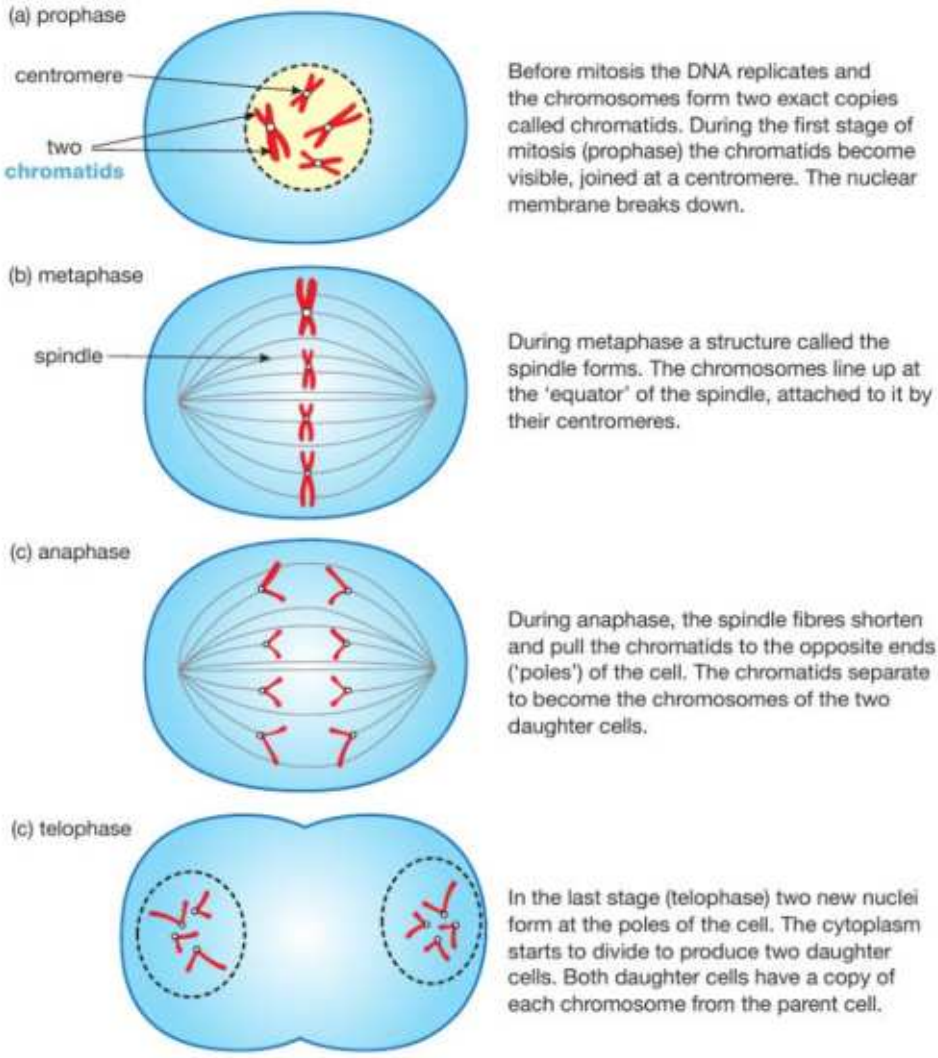
MITOSIS

When a 'parent' cell divides it produces 'daughter' cells. Mitosis produces two daughter cells that are genetically identical to the parent cell – both daughter cells have the same number and type of chromosomes as the parent cell.

To achieve this, the dividing cell must do two things.

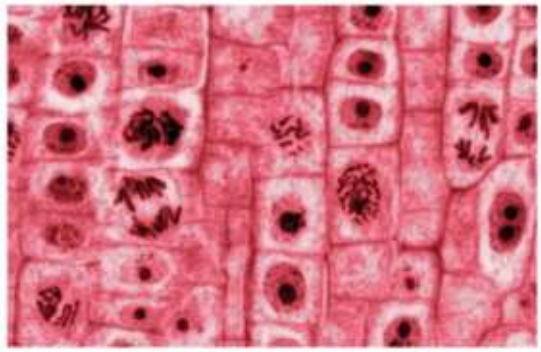
- It must copy each chromosome before it divides. This involves the DNA replicating and more proteins being added to the structure. Each daughter cell will then be able to receive a copy of each chromosome (and each molecule of DNA) when the cell divides.

- It must divide in such a way that each daughter cell receives one copy of every chromosome. If it does not do this, both daughter cells will not contain all the genes.



▲ Figure 17.1 The stages of mitosis. For simplicity the cell shown contains two homologous pairs of chromosomes (one long pair, one short). (You do not need to remember the names of the stages.)

A number of distinct stages occur when a cell divides by mitosis. These are shown in Figure 17.1. Figure 17.2 is a photograph of some cells from the root tip of an onion. Cells in this region of the root divide by mitosis to allow growth of the root.



▲ Figure 17.2 Cells in the root tip of an onion dividing by mitosis. Can you identify any of the stages shown in Figure 17.1?

Each daughter cell formed by mitosis receives a copy of every chromosome, and therefore every gene, from the parent cell. Each daughter cell is genetically identical to the others. All the cells in our body (except the gametes) are formed by mitosis from the zygote (single cell formed at fertilisation). They all, therefore, contain copies of all the chromosomes and genes of that zygote. They are all genetically identical.

Whenever cells need to be replaced in our bodies, cells divide by mitosis to make them. This happens more frequently in some regions than in others.

- The skin loses thousands of cells every time we touch something. This adds up to millions every day that need replacing. A layer of cells beneath the surface is constantly dividing to produce replacements.
- Cells are scraped off the lining of the gut as food passes along. Again, a layer of cells beneath the gut lining is constantly dividing to produce replacement cells.
- Cells in our spleen destroy worn out red blood cells at the rate of 100 000 000 000 per day! These are replaced by cells in the bone marrow dividing by mitosis. In addition, the bone marrow forms all our new white blood cells and **platelets**.
- Cancer cells also divide by mitosis. The cells formed are exact copies of the parent cell, including the mutation in the genes that makes the cells divide uncontrollably.

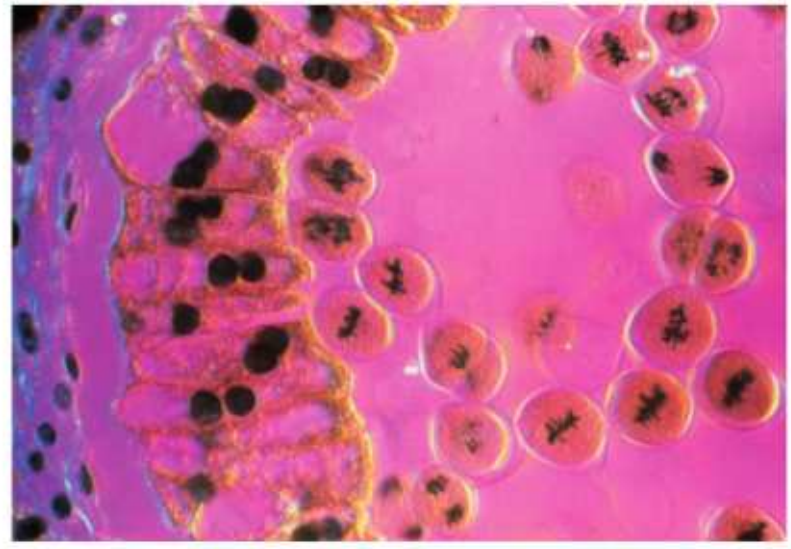
MEIOSIS

Meiosis forms gametes. It is a more complex process than mitosis and takes place in two stages called meiosis I and meiosis II, resulting in four haploid cells. Each daughter cell is genetically different from the other three and from the parent cell.

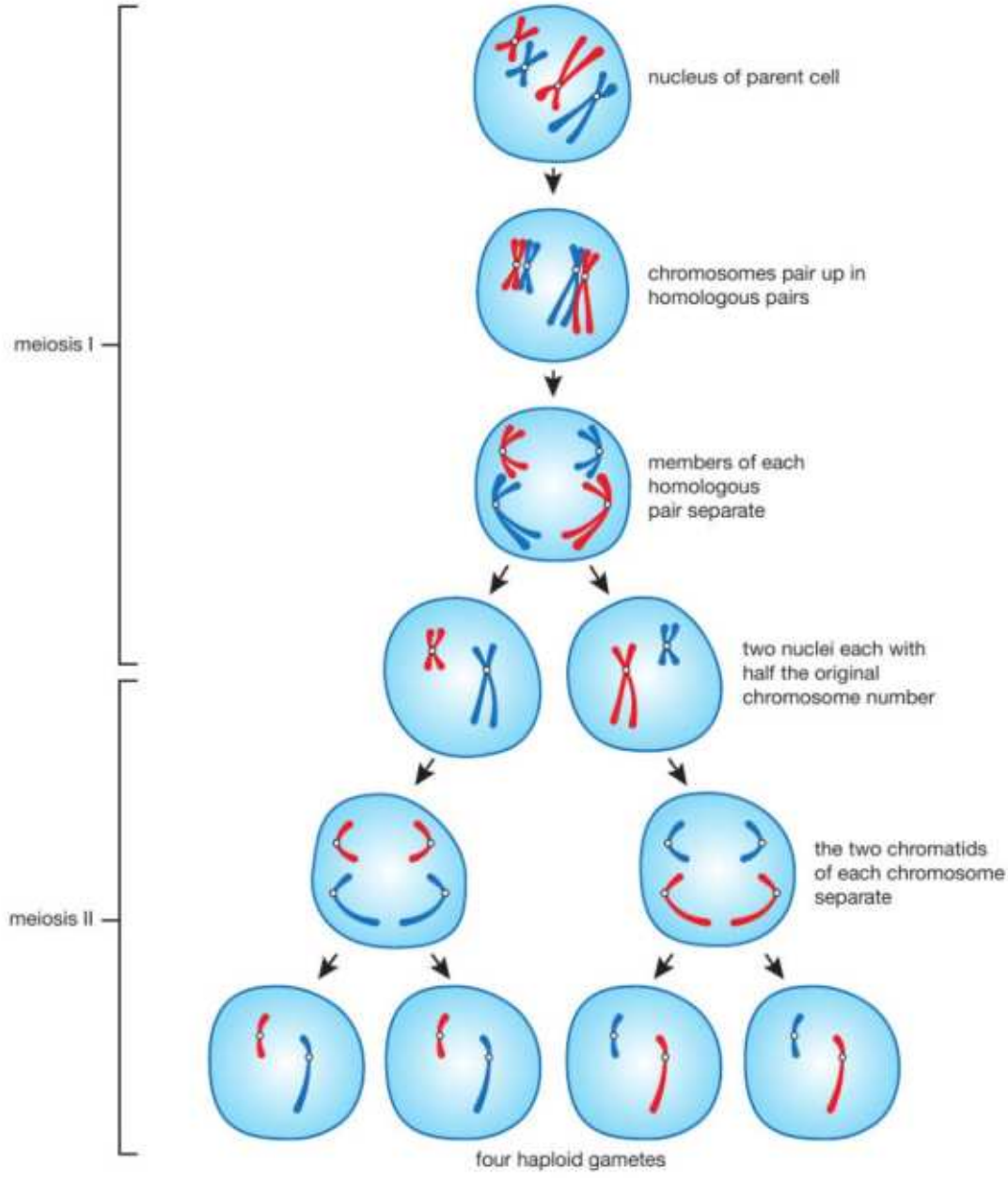
During meiosis the parent cell must do two things:

- It must copy each chromosome so that there is enough genetic material to be shared between the four daughter cells
- It must divide twice, in such a way that each daughter cell receives just one chromosome from each homologous pair.

These processes are summarised in Figure 17.4. Figure 17.3 shows cells in the anther of a flower dividing by meiosis.



▲ Figure 17.3 Photomicrograph of an anther showing cells dividing by meiosis.

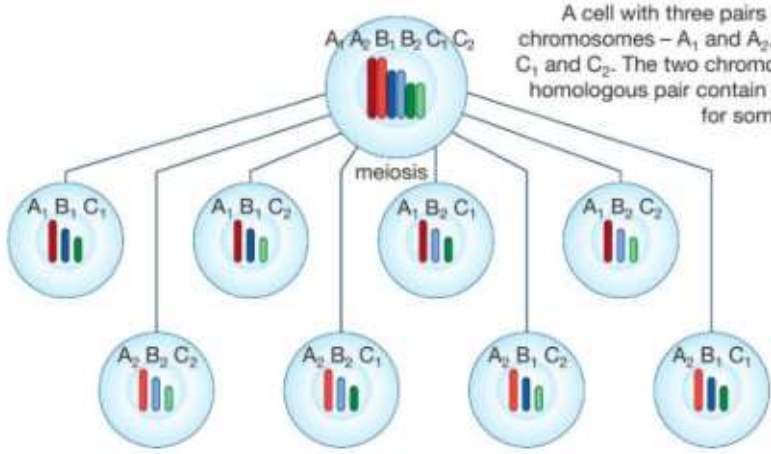


▲ Figure 17.4: The stages of meiosis. For simplicity the parent cell contains only two homologous pairs of chromosomes (one long pair, one short). To help you to see what happens, one member of each pair is coloured red and one blue. The cell membrane is shown, but the nuclear membrane has been omitted. A spindle forms during each division, but these have also been omitted for clarity.

There are two main events during meiosis:

- during the first division, one chromosome from each homologous pair goes into each daughter cell
- during the second division, the chromosome separates into two parts. One part goes into each daughter cell.

The gametes formed by meiosis don't all have the same combinations of alleles – there is *genetic variation* in the cells. During the two cell divisions of meiosis, the chromosomes of each homologous pair are shared between the two daughter cells independently of each of the other homologous pairs. This allows for much possible genetic variation in the daughter cells (Figure 17.5).



▲ Figure 17.5 How meiosis produces variation

Table 17.1 summarises the similarities and differences between mitosis and meiosis.

Table 17.1 Comparison of meiosis and mitosis.

Feature of the process	Mitosis	Meiosis
Chromosomes are copied before division begins	Yes	Yes
Number of cell divisions	One	Two
Number of daughter cells produced	Two	Four
Daughter cells are haploid or diploid	Diploid	Haploid
Genetic variation in the daughter cells	No	Yes

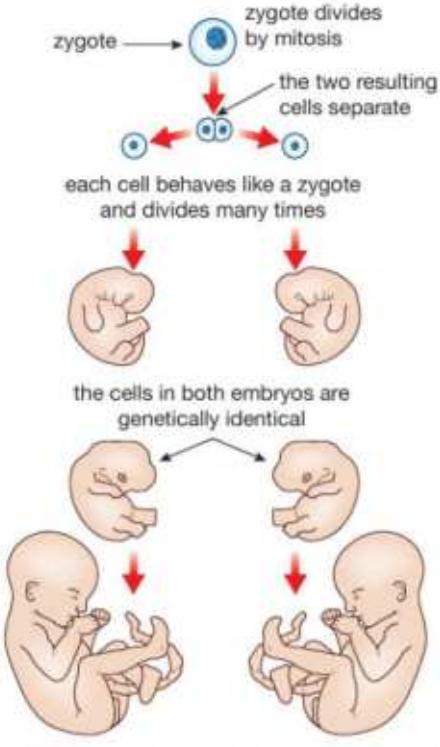
EXTENSION WORK

There is a mathematical rule for predicting how many combinations of chromosomes there can be. The rule is:

number of possible combinations = 2^n

where n = number of pairs of chromosomes.

With two pairs of chromosomes, the number of possible combinations = 2^2 = 4. With three pairs of chromosomes, the number of possible combinations = 2^3 = 8. With the 23 pairs of chromosomes in human cells, the number of possible combinations = 2^{23} = 8 388 608!



▲ Figure 17.6 How identical twins are formed

SEXUAL REPRODUCTION AND VARIATION

Sexual reproduction in any multicellular organism involves the fusion of two gametes to form a zygote. The offspring from sexual reproduction vary genetically for a number of reasons. One reason is because of the huge variation in the gametes. Another reason is because of the random way in which fertilisation takes place. In humans, any one of the billions of sperm formed by a male during his life could, potentially, fertilise any one of the thousands of ova formed by a female.

This variation applies to both male and female gametes. So, just using our 'low' estimate of about 8.5 million different types of human gametes means that there can be 8.5 million different types of sperm and 8.5 million different types of ova. When fertilisation takes place, any sperm could fertilise any ovum. The number of possible combinations of chromosomes (and genes) in the zygote is 8.5 million × 8.5 million = 7.2×10^{13}, or 72 trillion! And remember, this is using our 'low' number!

This means that every individual is likely to be genetically unique. The only exceptions are identical twins. Identical twins are formed from the *same* zygote – they are sometimes called *monozygotic* twins. When the zygote divides by mitosis, the two *genetically identical* cells formed do not 'stay together'. Instead, they separate and each cell behaves as though it were an individual zygote, dividing and developing into an embryo (Figure 17.6). Because they have developed from genetically identical cells (and, originally, from the same

zygote), the embryos (and, later, the children and the adults they become) will be genetically identical.

Non-identical twins develop from different zygotes and so are not genetically identical.

Seeds are made by sexual reproduction in plants. Each seed contains an embryo, which results from a pollen grain nucleus fusing with an egg cell nucleus. Embryos from the same plant will vary genetically because they are formed by different pollen grains fertilising different egg cells and so contain different combinations of genes.

ASEXUAL REPRODUCTION AND CLONING

KEY POINT

Cloning is a process that produces a group of genetically identical offspring (a **clone**) from part of the parent organism. Gametes are not involved.

Plant breeders have known for a long time that sexual reproduction produces variation. They realised that if a plant had some desirable feature, the best way to get more of that plant was not to collect and plant its seeds, but to **clone** it in some way. Modern plant-breeding techniques allow the production of many thousands of identical plants from just a few cells of the original (see Chapter 19).

When organisms reproduce asexually, there is no fusion of gametes. A part of the organism grows and somehow breaks away from the parent organism. The cells it contains were formed by mitosis, so contain exactly the same genes as the parent. Asexual reproduction produces offspring that are genetically identical to the parent, and genetically identical to each other.

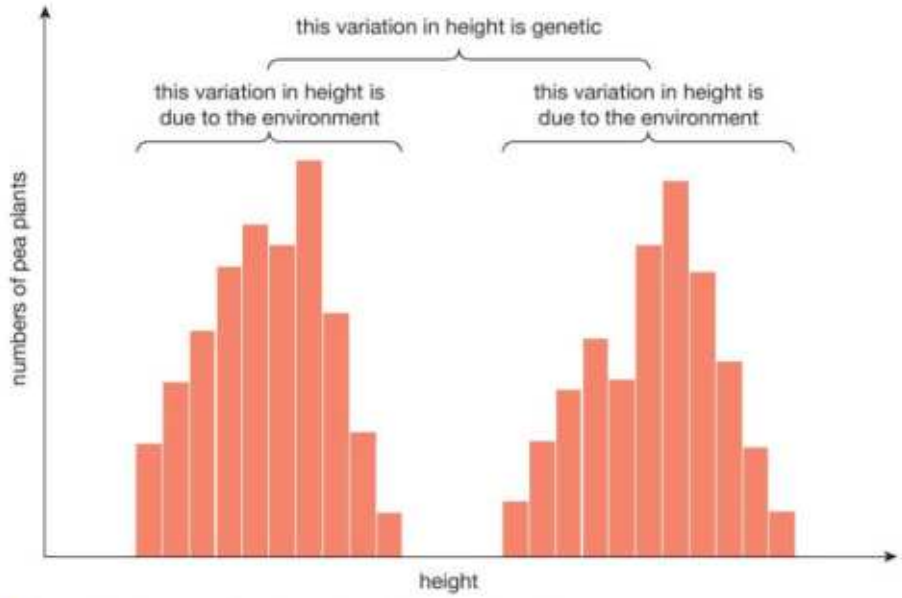
Asexual reproduction is common in plants (see Chapter 13). For example, flower bulbs grow and divide asexually each season to produce more bulbs. Asexual reproduction also occurs in some animals (see Chapter 9).

GENES AND ENVIRONMENT BOTH PRODUCE VARIATION

DID YOU KNOW?

Short pea plants are called 'dwarf' varieties. The genetics controlling the height of pea plants is described in Chapter 18.

There are two varieties of pea plants that are either tall or short. This difference in height is due to the genes they inherit. There are no 'intermediate height' pea plants. However, all the tall pea plants are not *exactly* the same height and neither are all the short pea plants *exactly* the same height. Figure 17.7 illustrates the variation in height of pea plants.



▲ Figure 17.7 Bar chart showing variation in height of pea plants.

Several environmental factors can influence the height of the plants.

- They may not all receive the same amount of light and so some will not photosynthesise as well as others.
- They may not all receive the same amount of water and mineral ions from the soil – this could affect the manufacture of a range of substances in the plant.
- They may not all receive the same amount of carbon dioxide. Again, some plants will not photosynthesise as well as others.

Similar principles apply in humans. Identical twins have the same genes, and often grow up to look very alike (although not quite identical). Also, they often develop similar talents. However, identical twins never look *exactly* the same. This is especially true if, for some reason, they grow up apart. The different environments affect their physical, social and intellectual development in different ways.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

More questions on cell division can be found at the end of Unit 5 on page 234.

1 A species of mammal has 32 chromosomes in its muscle cells. Which row in the table below shows the number of chromosomes in the mammal's skin cells and sperm cells?

	Skin cells	Sperm cells
A	32	32
B	16	16
C	16	32
D	32	16

2 Consider the following statements about reproduction in plants:

1. Large numbers of offspring are quickly produced

2. There is little genetic variation in the offspring.

3. A mechanism such as wind or insects is not needed for pollination.

Which of the above are advantages of *asexual* reproduction in plants?

A 1 and 2 **C** 2 and 3

B 1 and 3 **D** 1, 2 and 3

3 Mitosis results in two _____ cells, while meiosis results in _____ haploid cells

Choose the correct pair of answers to fill the gaps in the sentence:

A haploid / four **C** diploid / four

B diploid / two **D** haploid / two

4 In which of the following does meiosis occur?

A a developing plant embryo

B the anthers of a flower

C the skin of a mammal.

D the tip of a shoot of a plant

SKILLS CRITICAL THINKING

5 Cells can divide by mitosis or by meiosis.

a Give one similarity and two differences between the two processes.

b Do cancer cells divide by mitosis or meiosis? Explain your answer.

c Why is meiosis sometimes called a reduction division?

SKILLS REASONING

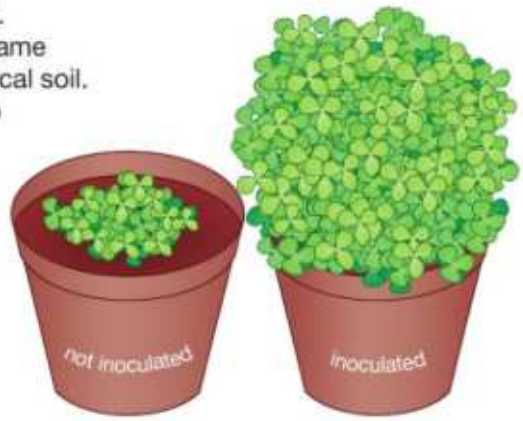
6 Daffodils reproduce sexually by forming seeds and asexually by forming bulbs. Explain why:

a the bulbs formed from a single daffodil plant produce plants very similar to each other and to the parent plant

b the seeds formed by a single daffodil plant produce plants that vary considerably.

SKILLS CRITICAL THINKING

7 The diagram shows two cuttings. They were both taken from the same clover plant and planted in identical soil. Both were left for several days to become established in their new pots. Some nitrogen-fixing bacteria were then added to the pot labelled 'inoculated'. The other pot was left untreated and labelled 'not inoculated'. The diagram shows the plants three weeks after the treatment to the 'inoculated' pot.



a What is the name given to the part of the experiment represented by the untreated pot of seeds?

SKILLS EXECUTIVE FUNCTION, REASONING

b Why were cuttings from the same plant used rather than seeds from the same plant?

SKILLS REASONING

c What does this experiment suggest about the influence of genes and the environment on variation in the height of clover plants?

SKILLS CRITICAL THINKING

8 Some cells divide by mitosis, others divide by meiosis. For each of the following examples, say whether mitosis or meiosis is involved. In each case, give a reason for your answers.

a Cells in the testes dividing to form sperm.

b Cells in the lining of the small intestine dividing to replace cells that have been lost.

c Cells in the bone marrow dividing to form white blood cells.

d Cells in an anther of a flower dividing to form pollen grains.

e A zygote dividing to form an embryo.

SKILLS CRITICAL THINKING, REASONING

9 Variation in organisms can be caused by the environment as well as by the genes they inherit. For each of the following examples, state whether the variation described is likely to be genetic, environmental or both. In each case, give a reason for your answers.

a Humans have brown, blue or green eyes.

b Half the human population is male, half is female.

c Cuttings of hydrangea plants grown in soils with different pH values develop flowers with slightly different colours.

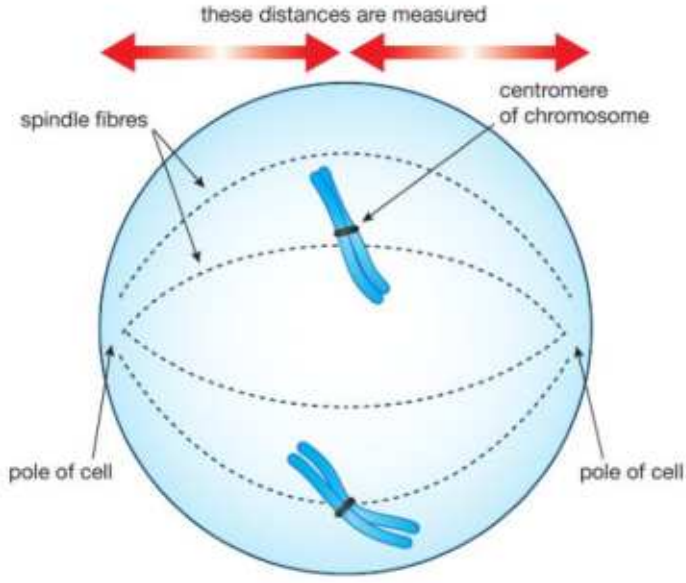
SKILLS CRITICAL THINKING, REASONING

d Some pea plants are tall; others are dwarf. However, the tall plants are not exactly the same height and neither are all the dwarf plants the same height.

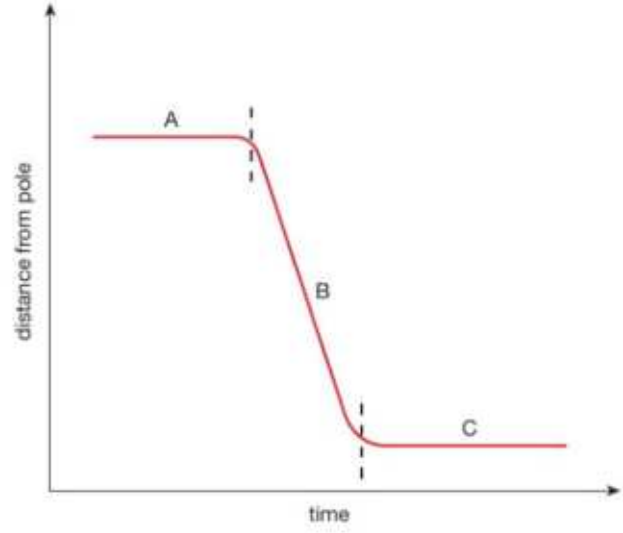
e People in some families are more at risk of heart disease than people in other families. However, not every member of the 'high risk' families have a heart attack and some members of the 'low risk' families do.

SKILLS ANALYSIS, INTERPRETATION

10 In an investigation into mitosis, the distance between a chromosome and the pole (end) of a cell was measured.



The graph shows how these distances changed during mitosis.



a Describe two events that occur during stage A.

b Explain what is happening during stage B.

c Describe two events that occur during stage C.

18 GENES AND INHERITANCE

How and why do we inherit features from our parents? This chapter answers these questions by looking at the work of Gregor Mendel and how he has helped us to understand the mysteries of inheritance.

LEARNING OBJECTIVES

- Understand that genes exist in alternative forms called alleles which give rise to differences in inherited characteristics
- Understand the meaning of the terms dominant, recessive, homozygous, heterozygous, phenotype and genotype
- Describe patterns of monohybrid inheritance using genetic diagrams
- Predict probabilities of outcomes from monohybrid crosses
- Understand how to interpret family pedigrees
- Understand how the sex of a person is controlled by one pair of chromosomes, XX in a female and XY in a male
- Describe the determination of the sex of offspring at fertilisation, using a genetic diagram
- Understand that most phenotypic features are the result of polygenic inheritance rather than single genes

The groundbreaking research that uncovered the rules of how genes are inherited was carried out by Gregor Mendel and published in 1865. The rules of inheritance are now known as 'Mendelian genetics' in his honour.

GREGOR MENDEL



▲ Figure 18.1 Gregor Mendel.

Gregor Mendel was a monk who lived in a monastery in Brno in what is now the Czech Republic (Figure 18.1). He became interested in the science of heredity, and carried out hundreds of breeding experiments using pea plants. From his research Mendel was able to explain the laws governing inheritance.

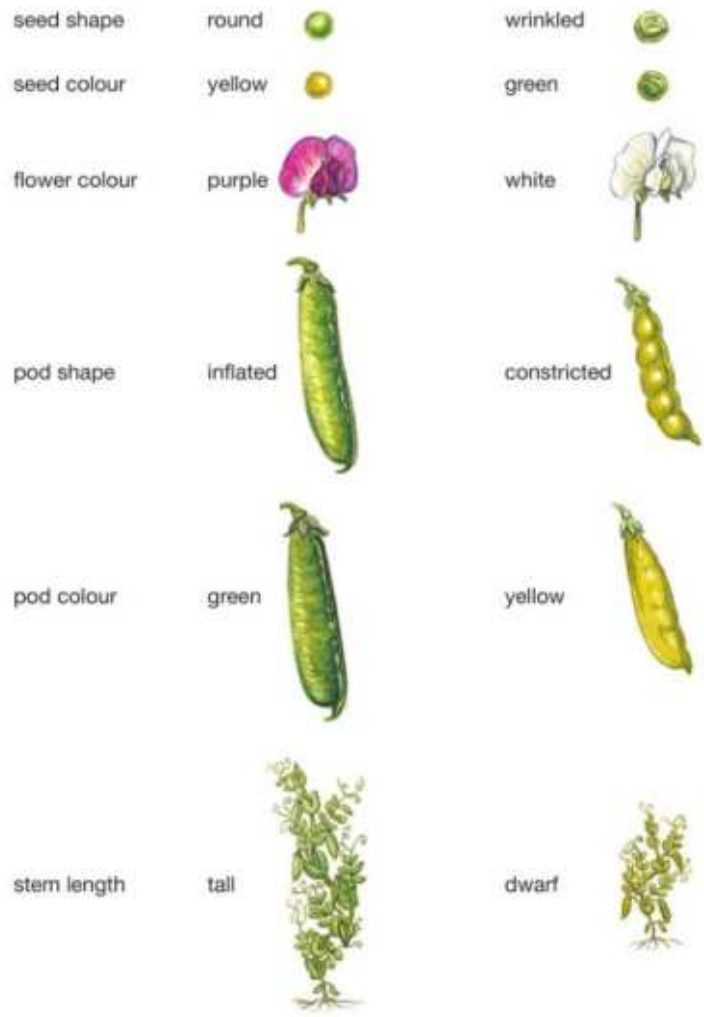
Mendel found that for every feature or 'character' he investigated:

- a 'heritable unit' (what we now call a **gene**) is passed from one generation to the next
- the heritable unit (gene) can have alternative forms (we now call these different forms **alleles**)
- each individual must have two alternative forms (alleles) per feature
- the gametes only have one of the alternative forms (allele) per feature
- one allele can be dominant over the other.

Mendel used these ideas to predict outcomes of cross-breeding or 'crosses' between plants, which he tested in his breeding experiments. He published his results and ideas in 1865 but few people took any notice, and his work went unrecognised for many years. It wasn't until 1900 that other biologists working on inheritance rediscovered Mendel's work and realised its importance. In 1903, the connection between the behaviour of genes in Mendelian genetics and the behaviour of chromosomes in meiosis was noticed and the science of genetics was established.

MENDEL'S EXPERIMENTS ON INHERITANCE

Mendel noticed that many of the features of pea plants had two alternative forms. For example, plants were either tall or very short (called a 'dwarf' variety); they either had purple or white flowers; they produced yellow seeds or green seeds. There were no intermediate forms, no pale purple flowers or green/yellow seeds or intermediate height plants. Figure 18.2 shows some of the contrasting features of pea plants that Mendel used in his breeding experiments.



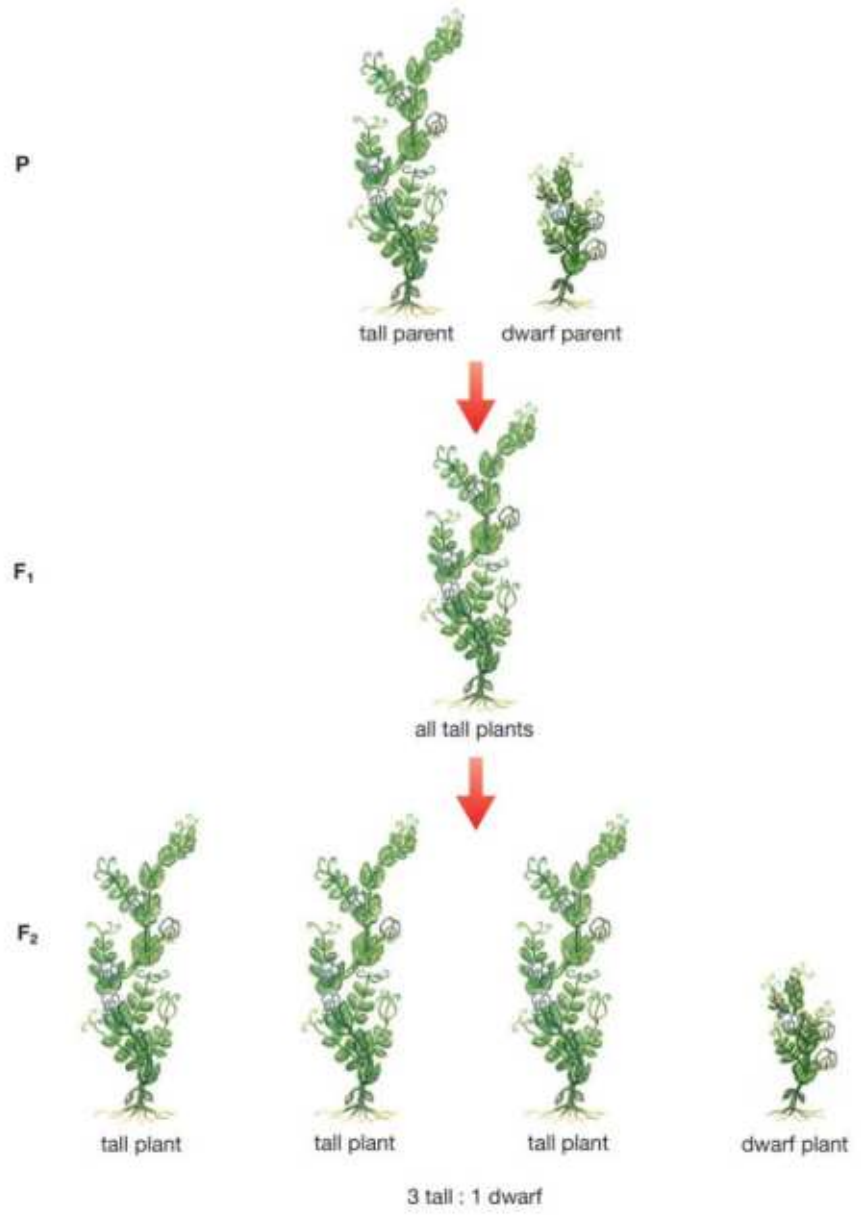
▲ Figure 18.2 Some features of pea plants used by Mendel in his breeding experiments.

KEY POINT

In his breeding experiments, Mendel initially used only plants that had 'bred true' for several generations. For example, any tall pea plants he used came from generations of pea plants that had all been tall.

Mendel decided to investigate, systematically, the results of cross breeding plants that had contrasting features. These were the 'parent plants', referred to as 'P' in genetic diagrams. He transferred pollen from one experimental plant to another. He also made sure that the plants could not be self-fertilised.

He collected all the seeds formed, grew them and noted the features that each plant developed. These plants were the first generation of offspring, called the **F_1 generation**. He did not cross-pollinate these plants, but allowed them to self-fertilise. Again, he collected the seeds, grew them and noted the features that each plant developed. These plants formed the second generation of offspring or **F_2 generation**. When Mendel used pure-breeding tall and pure-breeding dwarf plants as his parents, he obtained the results shown in Figure 18.3.



▲ Figure 18.3 A summary of Mendel's results from breeding tall pea plants with dwarf pea plants.

Mendel obtained similar results when he carried out breeding experiments using plants with other pairs of contrasting characters (Figure 18.4). He noticed two things in particular.

- All the plants of the F_1 generation were of one type. This type was not a blend of the two parental features, but one or the other. For example, when tall and dwarf parents were crossed, all the F_1 plants were tall.
- There was always a 3:1 ratio of types in the F_2 generation. Three-quarters of the plants in the F_2 generation were of the type that appeared in the F_1 generation. One-quarter showed the other parental feature. For example, when tall F_1 plants were crossed, three-quarters of the F_2 plants were tall and one-quarter were dwarf.

Mendel was able to use his findings to work out how features were inherited, despite having no knowledge of chromosomes, genes or meiosis. Nowadays we can use our understanding of these ideas to explain Mendel's results.

EXPLAINING MENDEL'S RESULTS

- Each feature is controlled by a gene, which is found on a chromosome.
- There are two copies of each chromosome and each gene in all body cells, except the gametes.
- The gametes have only one copy of each chromosome and each gene (i.e. one allele).
- There are two alleles of each gene.
- One allele is **dominant** over the other allele, which is **recessive**.
- When two different alleles (one dominant and one recessive) are in the same cell, only the dominant allele is expressed (shown in the appearance of the organism).
- An individual can have two dominant alleles, two recessive alleles or a dominant allele and a recessive allele in each cell.

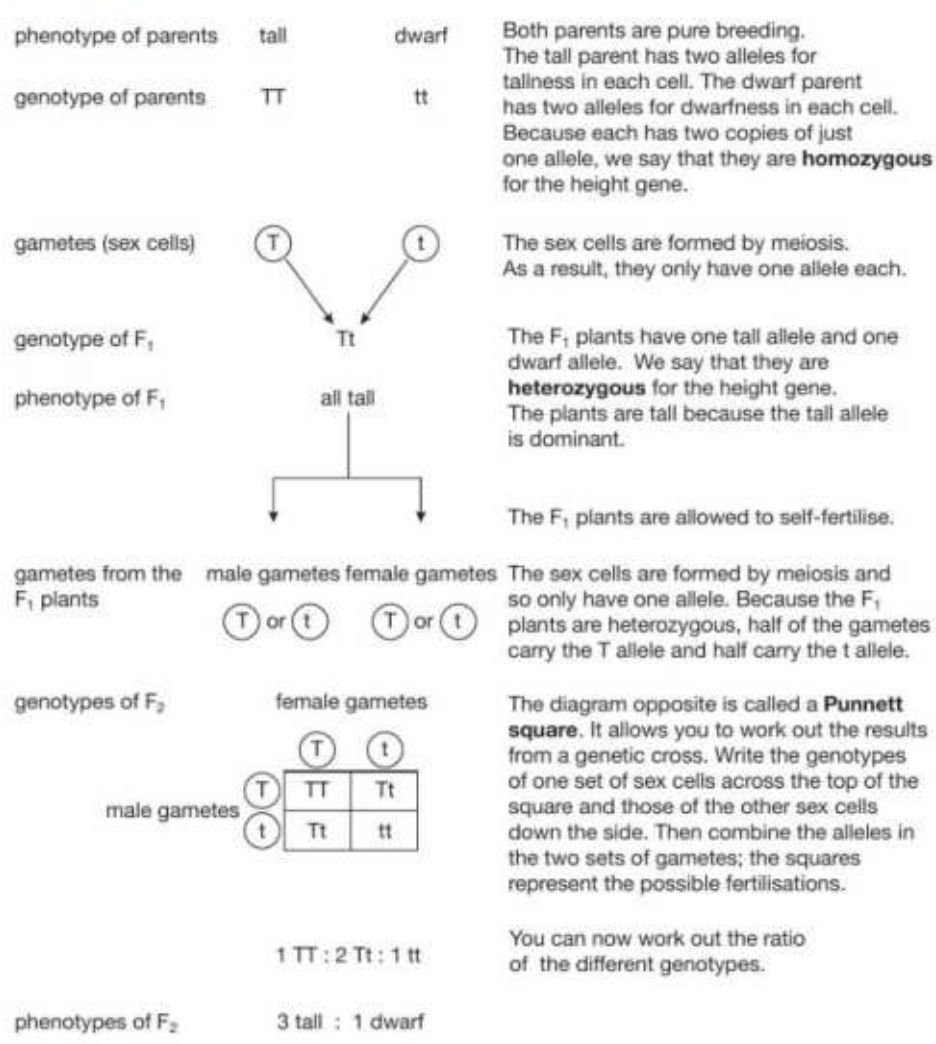
KEY POINT

Normally, we use the first letter of the dominant feature to represent the gene, with a capital letter indicating the dominant allele and a lower case letter the recessive allele. Tall is dominant to dwarf in pea plants, so we use T for the allele for tall and t for the dwarf allele.

We can use the cross between tall and dwarf pea plants as an example (Figure 18.4). In pea plants, there are tall and dwarf alleles of the gene for height. We will use the symbol T for the tall allele and t for the dwarf allele. The term **genotype** describes the alleles each cell has for a certain feature (e.g. TT). The **phenotype** is the feature that results from the genotype (e.g. a tall plant).

KEY POINT

It is the accepted practice in genetics diagrams to show the gene present in a gamete as a letter in a circle.



▲ Figure 18.4 Results of crosses using true-breeding tall and dwarf pea plants.

KEY POINT

Mendel's experiments described above, all involve single genes (e.g. the gene for height, or the gene for flower colour). The name given for inheritance involving one gene is **monohybrid** inheritance. It is possible to draw genetic diagrams involving two or more genes (e.g height and flower colour together), but for International GCSE you only need to interpret monohybrid crosses.

It is important to remember that in genetic crosses, ratios such as 3:1 are *predicted* ratios. In breeding experiments the *actual* numbers of offspring are unlikely to *exactly* fit a 3:1 ratio.

Imagine you flip a coin 20 times. The most likely outcome is that you will get 10 heads and 10 tails. However, you wouldn't be surprised to get, by chance, 11 heads and 9 tails, or 8 heads and 12 tails. The same principle applies to the outcome of a breeding experiment.

For example, one of Mendel's experiments produced 787 tall plants and 277 dwarf plants. This is a ratio of 2.84:1, not quite the expected 3:1. The reason for this is that there are a number of factors that affect survival of the plants – some pollen may not fertilise some ova, some seedlings may die before they mature, and so on. These are unpredictable or 'chance' events. The numbers that Mendel found were statistically close enough to the expected 3:1 ratio, and he found the same thing when he repeated his experiments with other characteristics.

WORKING OUT GENOTYPES – THE TEST CROSS

You cannot tell just by looking at a tall pea plant whether it is **homozygous** (TT) or **heterozygous** (Tt). Both these genotypes would appear equally tall because the tall allele is dominant.

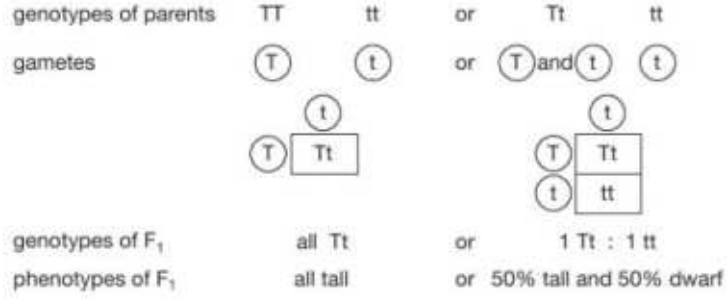
It would help if you knew the genotypes of its parents. You could then write out a genetic cross and perhaps work out the genotype of your tall plant. If you don't know the genotypes of the parents, the only way you can find out is by carrying out a breeding experiment called a **test cross**.

In a test cross, the factor under investigation is the unknown genotype of an organism showing the dominant phenotype. A tall pea plant could have the genotype TT or Tt. You must control every other possible variable *including the genotype of the plant you breed it with*. The only genotype you can be *certain* of is the genotype of plants showing the *recessive* phenotype (in this case dwarf plants). They *must* have the genotype tt.

KEY POINT

In a test cross, you breed an organism showing the dominant feature with one showing the recessive feature.

In this example, you must breed the 'unknown' tall pea plant (TT or Tt) with a dwarf pea plant (tt). You can write out a genetic cross for both possibilities (TT × tt and Tt × tt) and *predict* the outcome for each (Figure 18.5). You can then compare the result of the breeding experiment with the predicted outcome, to see which result matches the prediction most closely.



▲ Figure 18.5 A test cross

From our crosses we would expect:

- *all* the offspring to be tall if the tall parent was homozygous (TT)
- *half* the offspring to be tall and *half* to be dwarf if the tall parent was heterozygous (Tt).

WAYS OF PRESENTING GENETIC INFORMATION

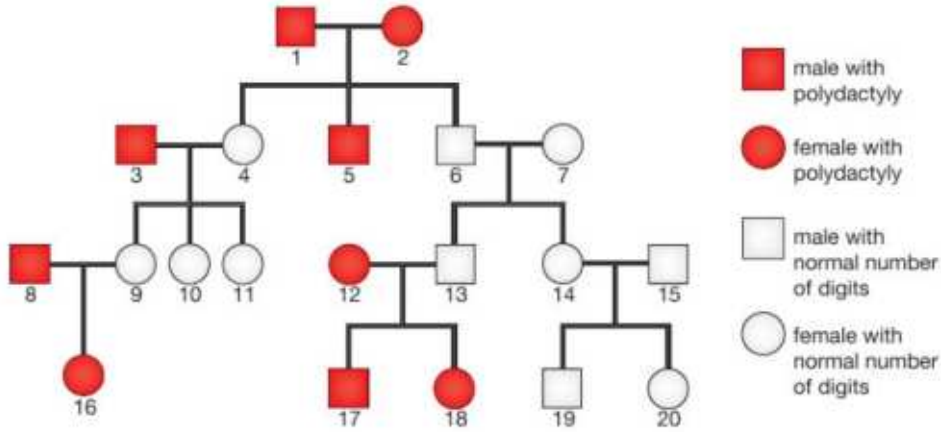
Writing out a genetic cross is a useful way of showing how genes are passed through one or two generations, starting from the parents. To show a family history of a genetic condition requires more than this. We can use a diagram called a **pedigree**.

Polydactyly is an inherited condition in which a person develops an extra digit (finger or toe) on the hands and feet. It is determined by a dominant allele. The recessive allele causes the normal number of digits to develop.

If we use the symbol D for the polydactyly allele and d for the normal-number allele, the possible genotypes and phenotypes are:

- DD – person has polydactyly (has two dominant polydactyly alleles)
- Dd – person has polydactyly (has a dominant polydactyly allele and a recessive normal allele)
- dd – person has the normal number of digits (has two recessive, normal-number alleles).

We don't use P and p to represent the alleles as you would expect, because the letters P and p look very similar and could easily be confused. The pedigree for polydactyly is shown in Figure 18.6.



▲ Figure 18.6 A pedigree showing the inheritance of polydactyly in a family.

We can extract a lot of information from a pedigree. In this case:

- there are four generations shown (individuals are arranged in four horizontal lines)
- individuals 4, 5 and 6 are children of individuals 1 and 2 (a family line connects each one directly to 1 and 2)
- individual 4 is the first-born child of 1 and 2 (the first-born child is shown to the left, then second born to the right of this, then the third born and so on)
- individuals 3 and 7 are not children of 1 and 2 (no family line connects them directly to 1 and 2)
- individuals 3 and 4 are father and mother of the same children – as are 1 and 2, 6 and 7, 8 and 9, 12 and 13, 14 and 15 (a horizontal line joins them).

It is usually possible to work out which allele is dominant from a pedigree. You look for a situation where two parents show the same feature and at least one child shows the contrasting feature. In Figure 18.6, individuals 1 and 2 both have polydactyly, but children 4 and 6 do not. There is only one way to explain this:

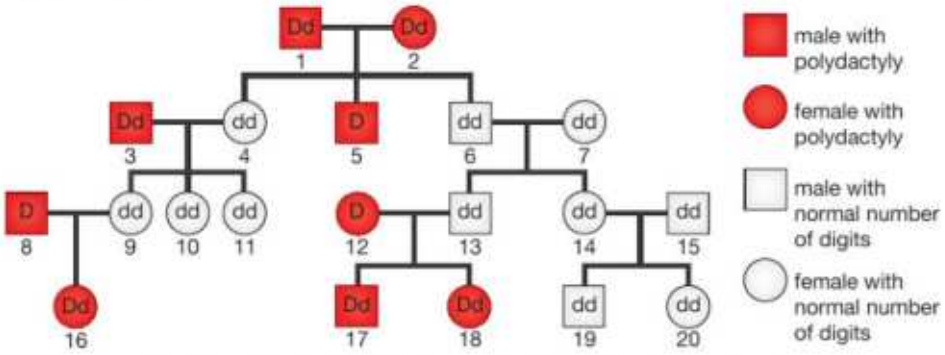
- the normal alleles in 4 and 6 can only have come from their parents (1 and 2), so 1 and 2 must both carry normal alleles
- 1 and 2 show polydactyly, so they must have polydactyly alleles as well
- if they have both polydactyly alleles *and* normal alleles but show polydactyly, the polydactyly allele must be the dominant allele.

Now that we know which allele is dominant, we can work out most of the genotypes in the pedigree. All the people with the normal number of digits *must* have the genotype dd (if they had even one D allele, they would show polydactyly). All the people with polydactyly must have at least one polydactyly allele (they must be either DD or Dd).

From here, we can begin to work out the genotypes of the people with polydactyly. To do this we need to remember that people with the normal number of digits must inherit one 'normal-number' allele from each parent, and also that people with the normal number of digits will pass on one 'normal-number' allele to each of their children.

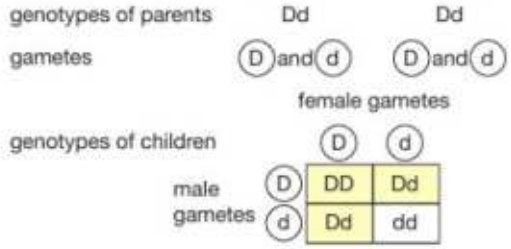
From this we can say that any person with polydactyly who has children with the normal number of digits must be heterozygous (the child must have inherited one of their two 'normal-number' alleles from this parent), and also that any person with polydactyly who has one parent with the normal number of digits must also be heterozygous (the 'normal-number' parent can only have passed on a 'normal-number' allele). Individuals 1, 2, 3, 16, 17 and 18 fall into one or other of these categories and must be heterozygous.

We can now add this genetic information to the pedigree. This is shown in Figure 18.7.



▲ Figure 18.7 A pedigree showing the inheritance of polydactyly in a family, with details of genotypes added.

We are still uncertain about individuals 5, 8 and 12. They could be homozygous or heterozygous. For example, individuals 1 and 2 are both heterozygous. Figure 18.8 shows the possible outcomes from a genetic cross between them. Individual 5 could be any of the outcomes indicated by the shading. It is impossible to distinguish between DD and Dd.



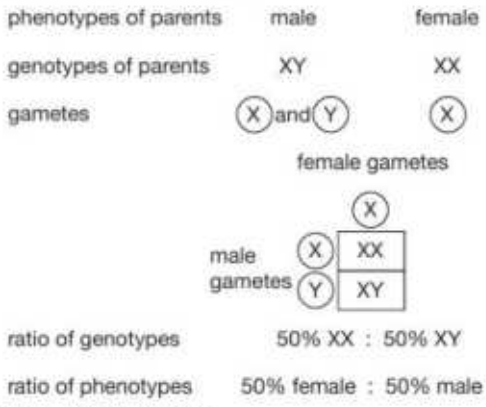
▲ Figure 18.8 Possible outcomes from a genetic cross between two parents, both heterozygous for polydactyly.

SEX DETERMINATION

Our sex – whether we are male or female – is not under the control of a single gene. It is determined by the X and Y chromosomes – the **sex chromosomes**. As well as the 44 non-sex chromosomes, there are two X chromosomes in all cells of females (except the egg cells) and one X and one Y chromosome in all cells of males (except the sperm). Our sex is effectively determined by the presence or absence of the Y chromosome. The full chromosome complement of male and female is shown in Figure 16.4 on page 198.

DID YOU KNOW?
Because the Y chromosome, when present, causes a zygote to develop into a male, some people describe it it as 'dominant'. This is incorrect: dominant and recessive are terms that are only applied to individual alleles.

The inheritance of sex follows the pattern shown in Figure 18.9. In any one family, however, this ratio may well not be met. Predicted genetic ratios are usually only met when large numbers are involved. The overall ratio of male and female births in all countries is 1 : 1.



▲ Figure 18.9 Determination of sex in humans

POLYGENIC INHERITANCE

All of the genetic crosses that you have seen in this chapter have been examples of inheritance involving single genes. The reason for this is that it is easier to draw genetics diagrams and explain what is happening if we start by considering alleles of a single gene. However, many characteristics are controlled by two or more genes working together. This is called **polygenic inheritance**.

DID YOU KNOW?
Melanin protects the skin against the harmful effects of ultraviolet radiation, which is a mutagen that can cause skin cancer.

A good example is human skin colour. Darker skins contain greater amounts of a black pigment called melanin. This is controlled by several genes, which act together to determine the amount of melanin in the skin. Each gene has alleles that promote melanin production and alleles which do not. This produces a wide range of phenotypes (Figure 18.10).



◀ Figure 18.10 Skin colour depends on the amount of melanin in the skin. It is a result of polygenic inheritance.

Other human characteristics determined by several genes (**polygenes**) are human height and body mass (weight).

CHAPTER QUESTIONS

More questions on chromosomes, genes and inheritance can be found at the end of Unit 5 on page 234.

SKILLS CRITICAL THINKING

1 Which of the following is true of dominant alleles?

A they are only expressed if present as a pair

B they determine the most favourable of a pair of alternative features

C they are inherited in preference to recessive alleles

D a dominant allele is expressed if present with a recessive allele

SKILLS PROBLEM SOLVING

2 In pea plants, the allele for purple petals is dominant to the allele for white petals. A plant heterozygous for petal colour was crossed with a plant with white petals. What would be the ratio of genotypes in the offspring?

A 1:1 **B** 2:1 **C** 1:0 **D** 3:1

3 The allele for yellow coat colour in mice (Y) is dominant to the allele for non-yellow coat colour (y).

Mice with the genotype yy have non-yellow coats.

Mice with the genotype Yy have yellow coats.

Mice with the genotype YY die as embryos.

Two heterozygous mice were crossed. What is the probability that a surviving mouse in the F1 generation will be yellow?

A 0.00 **B** 0.25 **C** 0.50 **D** 0.67

4 Predict the *ratios* of offspring from the following crosses between tall/dwarf pea plants.

a TT × TT

b TT × Tt

c TT × tt

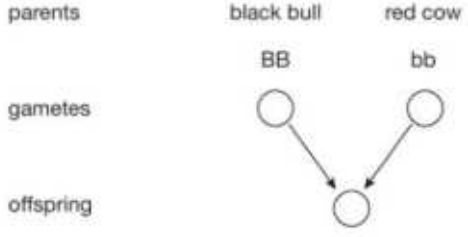
d Tt × Tt

e Tt × tt

f tt × tt.

SKILLS CRITICAL THINKING

5 In cattle, a pair of alleles controls coat colour. The allele for black coat colour is dominant over the allele for red coat colour. The genetic diagram represents a cross between a pure-breeding black bull and a pure-breeding red cow. B = dominant allele for black coat colour; b = recessive allele for red coat colour.



a i What term describes the genotypes of the pure-breeding parents?

ii Explain the terms dominant and recessive.

SKILLS CRITICAL THINKING

b i What are the genotypes of the gametes of each parent?

ii What is the genotype of the offspring?

c Cows with the same genotype as the offspring were bred with bulls with the same genotype.

i What genetic term describes this genotype?

SKILLS INTERPRETATION, PROBLEM SOLVING

ii Draw a genetic diagram to work out the ratios of:

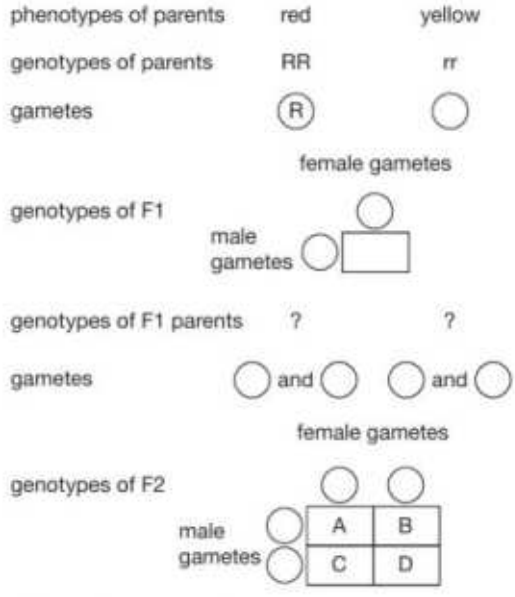
the genotypes of the offspring

the phenotypes of the offspring.

SKILLS INTERPRETATION

6 In nasturtiums, a single pair of alleles controls flower colour.

The allele for red flower colour is dominant over the allele for yellow flower colour. The diagram represents the results of a cross between a pure-breeding red-flowered nasturtium and a pure-breeding yellow-flowered nasturtium. R = dominant allele for red flower colour; r = recessive allele for yellow flower colour.



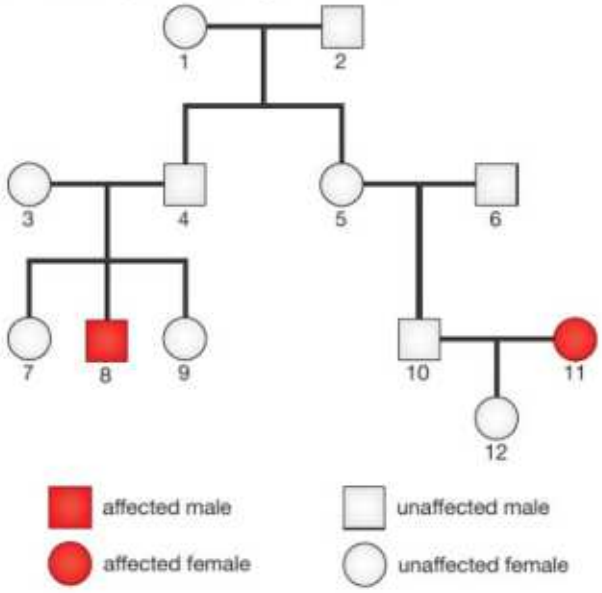
a Copy and complete the genetic diagram.

SKILLS ANALYSIS

b What are the colours of the flowers of A, B, C and D?

SKILLS ANALYSIS

7 Cystic fibrosis is an inherited condition. The diagram shows the incidence of cystic fibrosis in a family over four generations.



a What evidence in the pedigree suggests that cystic fibrosis is determined by a recessive allele?

b What are the genotypes of individuals 3, 4 and 11? Explain your answers.

c Draw genetic diagrams to work out the probability that the next child born to individuals 10 and 11 will

SKILLS INTERPRETATION

i be male,

ii suffer from cystic fibrosis.

SKILLS REASONING

8 In guinea pigs, the allele for short hair is dominant to that for long hair.

a Two short-haired guinea pigs were bred and their offspring included some long-haired guinea pigs. Explain these results.

b How could you find out if a short-haired guinea pig was homozygous or heterozygous for hair length?

19 NATURAL SELECTION, EVOLUTION AND SELECTIVE BREEDING

Over millions of years, life on this planet has evolved from its simple beginnings into the vast range of organisms present today. This has happened by a process called natural selection. This chapter looks at natural selection, as well as traditional methods of selective breeding and modern developments involving cloned organisms.

LEARNING OBJECTIVES

- Explain Darwin's theory of evolution by natural selection
- Understand how resistance to antibiotics can increase in bacterial populations
- Understand how selective breeding can be used to produce plants with desired characteristics
- Understand how selective breeding can be used to produce animals with desirable characteristics



▲ Figure 19.1 Charles Darwin (1809–1882).

The meaning of '**evolution**' is that species of animals and plants are not fixed in their form, but change over time. It is not a new idea. For thousands of years philosophers have discussed this theory. By the beginning of the nineteenth century there was overwhelming evidence for evolution, and many scientists had accepted that it had taken place. What was missing was an understanding of the *mechanism* by which evolution could have occurred.

The person who proposed the mechanism for evolution that is widely accepted today was the English biologist Charles Darwin (Figure 19.1). He called the mechanism **natural selection.**

THE WORK OF CHARLES DARWIN

Charles Darwin was the son of a country doctor. He did not do particularly well at school or university and was unable to decide on a profession. His father is supposed to have said: 'you're good for nothing but shooting guns and rat-catching … you'll be a disgrace to yourself and all of your family'. He was wrong – Darwin went on to become one of the most famous scientists of all time!

At the age of 22, Charles Darwin became the unpaid biologist aboard the survey ship HMS *Beagle*, which left England for a five-year voyage in 1831 (Figure 19.2).

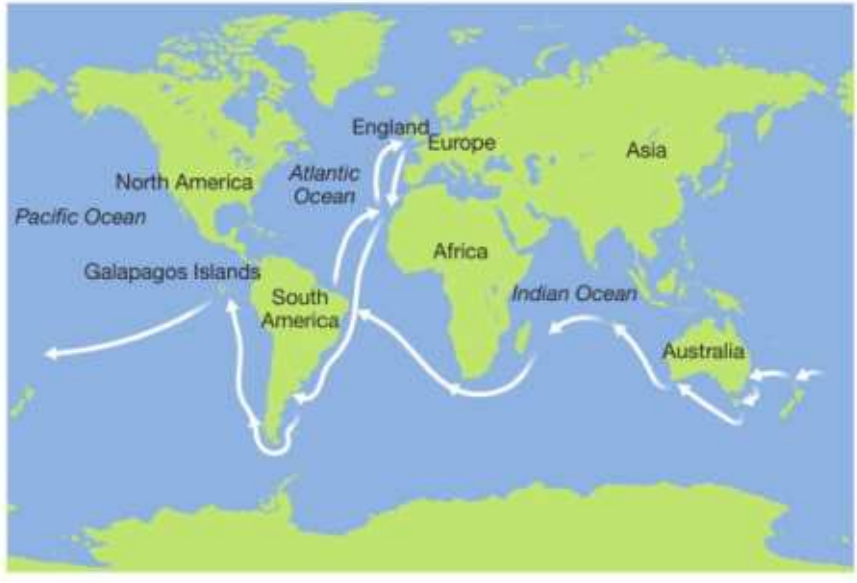


Figure 19.2 The five-year journey of HMS *Beagle* ▶

DID YOU KNOW?

A fossil is the remains of an animal or plant that lived thousands or millions of years ago, preserved in sedimentary rocks. Fossils are formed when minerals replace the materials in bone and tissue, creating a replica of the original organism in the rock.

During the voyage, Darwin collected hundreds of specimens and made many observations about the variety of organisms and the ways in which they were adapted to their environments. He gained much information, in particular, from the variety of life forms in South America and the Galapagos Islands. Darwin was influenced by the work of Charles Lyell who was, at the time, laying the foundations of modern geology. Lyell was using the evidence of rock layers to suggest that the surface of the Earth was constantly changing. The layers of sediments in rocks represented different time periods. Darwin noticed that the fossils found in successive layers of rocks often changed slightly through the layers. He suggested that life forms were continually changing – evolving.

On his return to England, Darwin began to evaluate his data and wrote several essays, introducing the ideas of natural selection. He arrived at his theory of natural selection from observations made during his voyage on HMS *Beagle* and from deductions made from those observations. Darwin's observations were that:

- organisms generally produce more offspring than are needed to replace them – a single female salmon can release 5 million eggs per year; a giant puffball fungus produces 40 million spores
- despite this over-reproduction, stable, established populations of organisms generally remain the same size – the seas are not overflowing with salmon, and we are not surrounded by lots of giant puffball fungi!
- members of the same species are not identical – they show variation.

He made two important deductions from these observations.

- From the first two observations he deduced that there is a 'struggle for existence'. Many offspring are produced, yet the population stays the same size. There must be competition for resources and many individuals must die.
- From the third observation he deduced that, if some offspring survive while others die, those organisms best suited to their environment would survive to reproduce. Those less suited will die. This gave rise to the phrase 'survival of the fittest'.

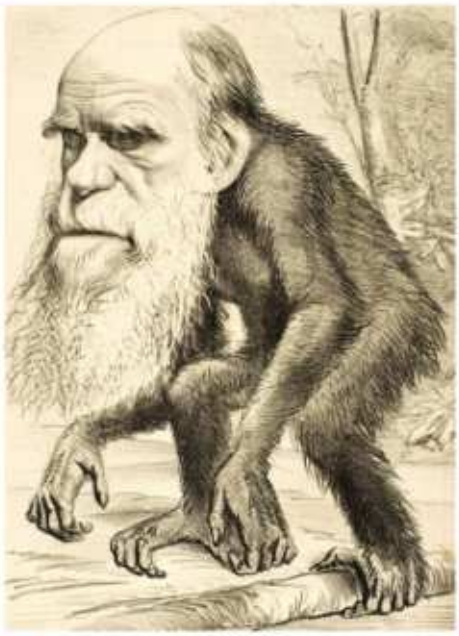
Notice a key phrase in the second deduction – the best-suited organisms survive *to reproduce*. This means that those characteristics that give the organism a better chance of surviving will be passed on to the next generation. Fewer of the individuals that are less suited to the environment survive to reproduce. The next generation will have more of the type that is better adapted and fewer of the less well adapted type. This will be repeated in each generation.

Another naturalist, Alfred Russell Wallace, had also studied life forms in South America and Indonesia and had reached the same conclusions as Darwin. Darwin and Wallace published a scientific paper on natural selection jointly, although it was Darwin who went on to develop the ideas further. In 1859, he published his now famous book *On the Origin of Species by Means of Natural Selection* (usually shortened to *The Origin of Species*).

This book changed forever the way in which biologists think about how species originate. Darwin went on to suggest that humans could have evolved from ape-like ancestors. For this he was ridiculed, largely by people who had misunderstood his ideas (Figure 19.3). He also carried out considerable research in other areas of biology, such as plant tropisms (see Chapter 12).

KEY POINT

The phrase 'survival of the fittest' does not mean *physical* fitness, but *biological* fitness. This depends on how well adapted an organism is to its environment so that it is successful in *reproducing*. A good way of putting it is; 'survival of the individuals that will leave most offspring in later generations'.



▲ Figure 19.3 Darwin's ideas were unpopular and many newspapers of the time made fun of them.

KEY POINT

When Darwin proposed his theory of natural selection, he did not know about genes and how they control characteristics. Gregor Mendel had yet to publish his work on inheritance, and as you have seen, the significance of Mendel's work was not recognised until 1903.

The theory of natural selection proposes that some factor in the environment 'selects' which forms of a species will survive to reproduce. Forms that are not well adapted will not survive.

The following is a summary of how we think natural selection works:

1. there is variation within the species
2. changing conditions in the environment (called a selection pressure) favours one particular form of the species (which has a selective advantage)
3. the frequency of the favoured form increases (it is selected for) under these conditions (survival of the fittest)
4. the frequency of the less well adapted form decreases under these conditions (it is selected against).

As you have seen, many gene mutations are harmful, and cells that carry them will not usually survive. Some mutations are 'neutral' and if they arise in the gametes, may be passed on without affecting the survival of the offspring. However, a few mutations can actually be beneficial to an organism. Beneficial mutations are the 'raw material' that are ultimately the source of new inherited variation.

SOME EXAMPLES OF HOW NATURAL SELECTION MIGHT HAVE WORKED

THE HOVERFLY

(a)



(b)



▲ Figure 19.4 Two insects showing 'warning colouration'. (a) A wasp, which has a sting. (b) A harmless hoverfly.

Figure 19.4 shows two species of insect: a wasp and a hoverfly. Wasps can defend themselves against predators using a sting. They also have a body with yellow and black stripes. This is called a 'warning colouration'. Predators such as birds soon learn that these colours mean that wasps have the sting, and they avoid attacking them.

Hoverflies do not have a sting. However, they have an appearance that is very like a wasp, with similar yellow and black stripes – they are 'mimics' of wasps. Predators treat hoverflies as if they do have a sting.

Clearly, mimicking a wasp is an advantage to the hoverfly. How could they have evolved this appearance? We can explain how it could have happened by natural selection.

The selection pressure was predation by birds and other animals. Among the ancestors of present-day hoverflies there would have been variation in colours. As a result of mutations, some hoverflies gained genes that produced stripes on their bodies. These insects were less likely to be eaten by predators than hoverflies without the stripes – they had a *selective advantage*.

Since the hoverflies with stripes were more likely to survive being eaten, they were more likely to reproduce, and would pass on the genes for stripes to their offspring. This process continued over many generations. Gradually more mutations and selection for 'better' stripes took place, until the hoverflies evolved the excellent warning colouration that they have today.

KEY POINT

Note that perfect stripes didn't have to appear straight away. Even a slight stripy appearance could give a small selective advantage over hoverflies without stripes. This would be enough to result in an increase in stripy hoverflies in the next generation.

THE POLAR BEAR



▲ Figure 19.5 A polar bear hunting on the Arctic sea ice.

The polar bear lives in the Arctic, inhabiting landmasses and sea ice covering the waters within the Arctic Circle (Figure 19.5). It is a large predatory carnivore, mainly hunting seals. One way the bear hunts is to wait near holes in the ice where seals come up to breathe. It also silently approaches and attacks seals that are resting on the ice.

Polar bears have many **adaptations** that suit them to their habitat. These include:

- a thick layer of white fur, which reduces heat loss and acts as camouflage in the snow
- wide, large paws. These help with walking in the snow, and are used for swimming
- strong, muscular legs – a bear can swim continuously in the cold Arctic waters for days
- nostrils that close when the bear is swimming under water
- a large body mass. Polar bears are the largest bears on Earth. An adult male averages 350 to 550 kilograms, and the record is over 1000 kilograms. This large size results in the animal having a small surface area to volume ratio, which reduces heat loss
- a 10 centimetre thick layer of insulating fat under the skin
- a well developed sense of smell – used to detect the bear's prey
- bumps on the pads of the paws to provide grip on the ice
- short, powerful claws, which also provide grip, and are needed for holding the heavy prey.

DID YOU KNOW?

Polar bear fur appears to be white, but in fact the individual hairs are actually transparent. The white colour results from light being refracted through the clear hair strands.

The polar bear is thought to have evolved from a smaller species, the brown bear, about 150,000 years ago. How did it evolve its adaptations for life in the Arctic? Let's consider just one of the adaptations, the thick white fur.

There are two main selection pressures in favour of thick white fur. The first is the need for insulation to reduce heat loss. The polar bear often has to survive temperatures of –30°C, and temperatures in the Arctic can fall as low as –70°C. The second is camouflage; white fur camouflages the animal against the snow so that it can approach its prey unseen and then attack it.

Among the brown bears that were the ancestors of the polar bear there would have been variations in fur length and colour. When some of these bears came to live in colder, more northerly habitats, those individuals with longer and paler fur would have had a selective advantage over others with shorter, darker fur. Any gene mutations that produced long, pale fur increased this advantage. Bears with these genes were less likely to die from the cold, or from lack of food. As a result, well-adapted bears were more likely to reproduce and pass on their genes. Over many thousands of years more mutations and selection for long, white fur produced the adaptation we see in the polar bear today. The same process of natural selection is thought to have happened to bring about the other adaptations shown by the polar bear.

CAN WE OBSERVE NATURAL SELECTION IN ACTION?

Most animals and plants reproduce slowly, so it takes a long time for natural selection to have an observable effect. To observe natural selection happening we can study organisms that reproduce quickly, such as bacteria or insects.

ANTIBIOTIC RESISTANCE IN BACTERIA



▲ Figure 19.6 This photo shows a colony of bacteria growing on a petri dish of nutrient agar. The circular discs contain different antibiotics. The discs have clear areas around them, where the bacteria have been killed by the antibiotic diffusing out from the discs.

Antibiotics are chemicals that kill or reduce the growth of microorganisms (Figure 19.6). They are used in medicine mainly to treat bacterial infections, although a few antibiotics are effective against fungal pathogens. Antibiotics do not work on viruses, so they are no use in treating any disease caused by a virus.

Natural antibiotics are produced by bacteria and fungi. They give a microorganism an advantage over other microorganisms when competing for nutrients and other resources, since the antibiotic kills the competing organisms.

Alexander Fleming discovered the first antibiotic in 1929. It is made by the mould *Penicillium*, and is called **penicillin**. Penicillin kills bacteria, and was first used to treat bacterial infections in the 1940s. Since then other natural antibiotics have been discovered, and many more have been chemically synthesised in laboratories. The use of antibiotics has increased dramatically, particularly over the last 20 years. We now almost expect to be given an antibiotic for even the most minor of ailments. This can be dangerous, as it leads to the development of bacterial resistance to antibiotics, so that the antibiotics are no longer effective in preventing bacterial infection.

DID YOU KNOW?

A particularly worrying example of a resistant bacterium is MRSA. MRSA stands for methicillin-resistant *Staphylococcus aureus*. It is sometimes called a 'super bug' because it is resistant to many antibiotics including methicillin (a type of penicillin). It is a particular problem in hospitals where it is responsible for many difficult-to-treat infections.

Resistance starts when a random mutation gives a bacterium resistance to a particular antibiotic. In a situation where the antibiotic is widely used, the new resistant bacterium has an advantage over non-resistant bacteria of the same type. The resistant strain of bacterium will survive and multiply in greater numbers than the non-resistant type. Bacteria reproduce very quickly – the generation time of a bacterium (the time it takes to divide into two daughter cells) can be as short as 20 minutes. This means that there could be 72 generations in a single day, producing a population of millions of resistant bacteria.

Resistant bacteria will not be killed by the antibiotic, meaning the antibiotic is no longer effective in controlling the disease.

Bacterial resistance to antibiotics was first noticed in hospitals in the 1950s, and has grown to be a major problem today. The resistant bacteria have a selective advantage over non-resistant bacteria – they are 'fitter'. In effect, the bacteria have evolved as a result of natural selection.

Doctors are now more reluctant to prescribe antibiotics. They know that by using them less, the bacteria with resistance have less of an advantage and will not become as widespread.

HINT

Some people talk about bacteria becoming *immune* to antibiotics. This is a misunderstanding. Immunity happens in people – we become immune to microorganisms that infect us, as a result of the immune response.

Bacteria become *resistant* to antibiotics.

PESTICIDE RESISTANCE IN INSECTS

Just as pathogenic bacteria can become resistant to antibiotics, insect pests can develop resistance to insecticides. The powerful insecticide DDT was first used in the 1940s (see Chapter 15). By the 1950s many species of insect (e.g. mosquitoes) appeared to be resistant to DDT. The resistant insects had developed a gene mutation that stopped them being killed by the insecticide.

While DDT continued to be used, the resistant insects had a selective advantage over the non-resistant ones. They survived to breed, so that with each generation the numbers of resistant insects in the population increased.

The same thing has happened with modern insecticides. There are now hundreds of examples of insect pests that have developed resistance to different insecticides.

SELECTIVE BREEDING

About 12000 years ago, the human way of life changed significantly. Humans began to grow plants and keep animals for milk and meat. They became farmers rather than hunters. This change first took place in the Middle East. Similar changes took place a little later in the Americas (where potatoes and maize were being grown) and in the Far East (where rice was first cultivated).

In the Middle East, humans first grew the cereal plants wheat and barley, and kept sheep and goats. Later, their livestock included cattle and pigs. Cultivating crops and keeping stock animals made it possible for permanent settlements to appear – life in villages began. Because of the more certain food supply, there was spare time, for the first time ever, for some people to do things other than hunt for food.

Ever since the cultivation of the first wheat and barley and the domestication of the first stock animals, humans have tried to obtain bigger yields from them. They cross-bred different maize plants (and barley plants) to obtain strains that produced more grain. They bred sheep and goats to give more milk and meat – selective breeding had begun. Today, animals and plants are bred for more than just food. For example, animals are used to produce a range of medicines and for research into the action of drugs.

Selective breeding is best described as the breeding of only those individuals with desirable features. It is sometimes called '**artificial selection**', as human choice, rather than environmental factors, is providing the selection pressure (compare this with natural selection, described above).

The methods used today for selective breeding are very different from those used only 50 years ago. Modern gene technology makes it possible to create a new strain of plant within weeks, rather than years.

TRADITIONAL SELECTIVE BREEDING

PLANTS

Traditionally, farmers have bred crop plants of all kinds to obtain increased yields. Probably the earliest example of selective breeding was the cross-breeding of strains of wild wheat. The aim was to produce wheat with a much increased yield of grain and with shorter, stronger stems (Figure 19.7). This wheat was used to make bread.



1 About 11 000 years ago, two strains of wild wheat were cultivated by farmers. Initially, all attempts at cross-breeding to produce wheats with a better yield gave only sterile offspring.

2 About 8000 years ago, a fertile hybrid wheat appeared from these two wild wheats. This was called emmer wheat and had a much higher yield than either of the original wheats.

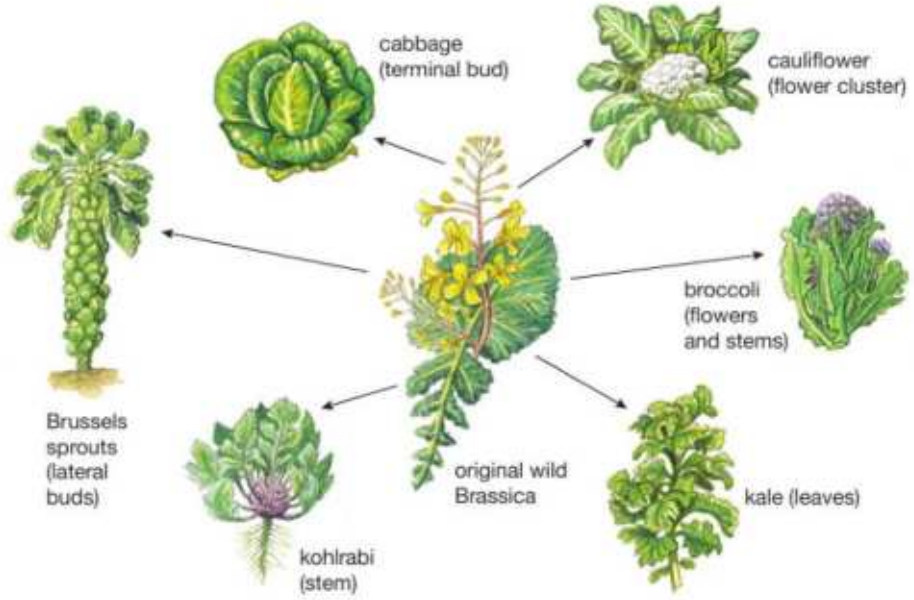
3 The emmer wheat was cross-bred with another wild wheat to produce wheat very similar to the wheats used today to make bread. This new wheat had an even bigger yield and was much easier to 'process' to make flour.

▲ Figure 19.7 Modern wheat is the result of selective breeding by early farmers.

DID YOU KNOW?

The production of modern bread wheats by selective breeding is probably one of the earliest examples of producing genetically modified food. Each original wild wheat species had 14 chromosomes per cell. The wild emmer hybrid had 28 chromosomes per cell. Modern bread wheat has 42 chromosomes per cell. Selective breeding has modified the genetic make-up of wheat.

Other plants have been selectively bred for certain characteristics. *Brassica* is a genus of cabbage-like plants. One species of wild brassica (*Brassica olera*) was selectively bred to give several strains, each with specific features (see Figure 19.8). Some of the strains had large leaves, others had large flower heads, and others produced large buds.



▲ Figure 19.8 Selectively breeding the original wild brassica plants to enhance certain features has produced several familiar vegetables.

Selective breeding has produced many familiar vegetables. Besides the ones produced from *Brassica*, selective breeding of wild *Solanum* plants has produced the many strains of potatoes that are eaten today. Carrots and parsnips are also the result of selective breeding programmes. Crop plants are bred to produce strains that:

- give higher yields
- are resistant to certain diseases (the diseases would reduce the yields)
- are resistant to certain insect pest damage (the damage would reduce the yield)
- are hardier (so that they survive in harsher climates or are productive for longer periods of the year)
- have a better balance of nutrients in the crop (for example, plants that contain more of the types of amino acids needed by humans).

DID YOU KNOW?

Plant breeders do not just breed plants for food. Nearly all garden flowers are the result of selective breeding. Breeders have selected flowers to have a particular size, shape, colour and fragrance. Roses and orchids are among the most selectively bred of our garden plants.

Figure 19.9 shows a field of potato plants. Some have been bred to be resistant to insect pests, while others were not selectively bred in this way.



▲ Figure 19.9 Selective breeding can reduce damage by pests. The plants on the right have been bred to be resistant to a fungal pest. Plants on the left are not resistant to the pest.

ANIMALS

Farmers have bred stock animals for similar reasons to the breeding of crops. They have selected for animals that:

- produce more meat, milk or eggs
- produce more fur or better quality fur
- produce more offspring
- show increased resistance to diseases and parasites.

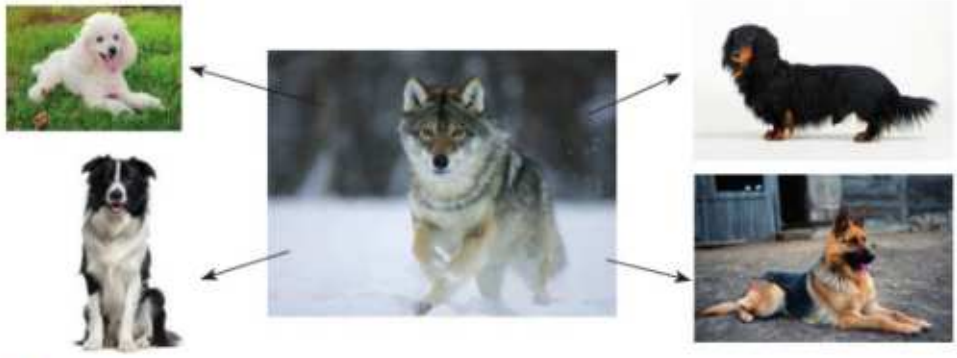
Again, like crop breeding, breeding animals for increased productivity has been practised for thousands of years. A stone tablet found in Iran appears to record the results of breeding domesticated donkeys. It was dated at over 5000 years old.

For many thousands of years, the only way to improve livestock was to mate a male and a female with the features that were desired in the offspring. In cattle, milk yield is an important factor and so high-yielding cows would be bred with bulls from other high-yielding cows.

Since about 1950, the technique of **artificial insemination (AI)** has become widely available. Bulls with many desirable features are kept and semen is obtained from them. The semen is diluted, frozen and stored. Farmers can buy quantities of this semen to inseminate their cows. the semen is transferred into the cow's uterus using a syringe. AI makes it possible for the semen from one prize bull to be used to fertilise many thousands of cows.

Modern sheep are domesticated wild sheep, and cows have been derived from wild aurochs. Just think of all the varieties of dogs that now exist. All these have been derived from one ancestral type. This original 'dog' was a domesticated wolf (Figure 19.10). In domesticating the wolf, humans gained an animal that

was capable of herding stock animals. The sheepdog has all the same instincts as the wolf except the instinct to kill. This has been selectively 'bred out'.



▲ Figure 19.10 The many different breeds of dog all originate from a common ancestor – the wolf.

CHAPTER QUESTIONS

More questions on natural selection, evolution and selective breeding can be found at the end of Unit 5 on page 234.

SKILLS CRITICAL THINKING

1 Which of the following statements is/are correct?

1. Antibiotics are made by bacteria
2. Antibiotics kill bacteria
3. Antibiotics do not work on viruses

A 1 and 2 **B** 2 only

C 2 and 3 **D** 1, 2 and 3

2 Which of the following best describes the meaning of biological 'fitness'

A a measure of an organism's ability to survive in different habitats

B a measure of the reproductive success of an organism

C a measure of the relative health of an organism

D a measure of the strength of an organism

3 What is the source of genetic variation?

A mutations

B mitosis

C selection pressures

D changes in the environment

4 Why is natural selection easy to observe in bacteria?

A they are very small

B they can be killed by antibiotics

C they are composed of simple cells

D they reproduce very quickly

5 Which of the following is another term for selective breeding?

A cloning **B** natural selection

C artificial insemination **D** artificial selection

SKILLS CRITICAL THINKING

6 Which of the following best describes artificial insemination?

A transplanting an embryo in the uterus

B taking sperm and placing it directly in the uterus

C selectively breeding healthy animals

D fertilisation of an egg in a test tube

7 a What does the term 'survival of the fittest' mean?

b Which two biologists arrived at the same idea concerning the 'survival of the fittest' at the same time?

8 Antibiotics are chemicals that are used to kill pathogens.

a What is a pathogen?

b Name two types of organism that make natural antibiotics.

SKILLS REASONING

c Some antibiotics are no longer effective in killing pathogens. Use your understanding of natural selection to explain why.

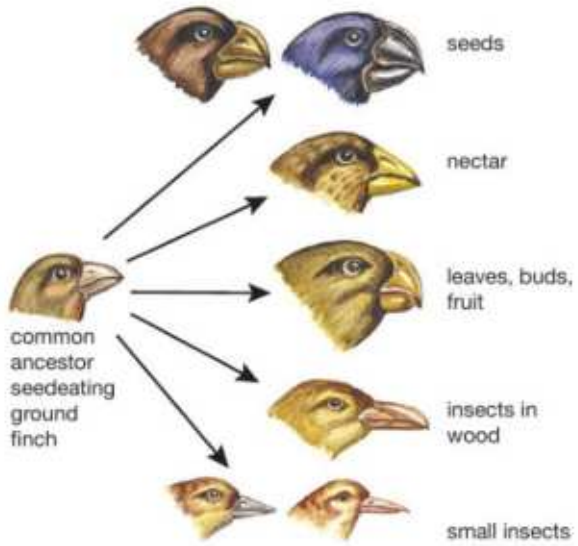
9 Warfarin is a pesticide that was developed to kill rats. When it was first used in 1950, it was very effective. Some rats, however, had a mutant allele that made them resistant to warfarin. Nowadays the pesticide is much less effective.

a Use the ideas of natural selection to explain why warfarin is much less effective than it used to be.

b Suggest what might happen to the number of rats carrying the allele for warfarin resistance, if warfarin were no longer used. Explain your answer.

SKILLS ANALYSIS

10 In the Galapagos Islands, Charles Darwin identified a number of species of birds, now known as Darwin's finches. He found evidence to suggest that they had all evolved from one ancestral type, which had colonised the islands from South America. The main differences between the finches were their beaks. The diagram shows some of the beak types and that of the likely ancestral finch.



a Explain how the seed-eating finches are adapted to their environment.

b Explain how the finches that eat insects and live in woodland are adapted to their environment.

SKILLS REASONING

c Use the information in the diagram to help you explain how the common ancestor could have evolved into the different type of finches.

SKILLS CRITICAL THINKING

11 Read the description below and answer the questions that follow.

Natural selection happens when a selection pressure favours individuals with particular characteristics, so that they have a selective advantage.

Some plants growing in areas contaminated by waste from mines have developed a tolerance to toxic metals such as lead and copper. They are able to grow on polluted soil, while non-tolerant plants are killed by the metals in the soil.

a How did the new tolerant varieties of plants arise?

b With reference to this example, explain the terms

i selection pressure

ii selective advantage

iii natural selection

SKILLS REASONING

c When metal-tolerant plants are grown on uncontaminated soil, they are out-competed by non-tolerant plants. Suggest a reason for this.

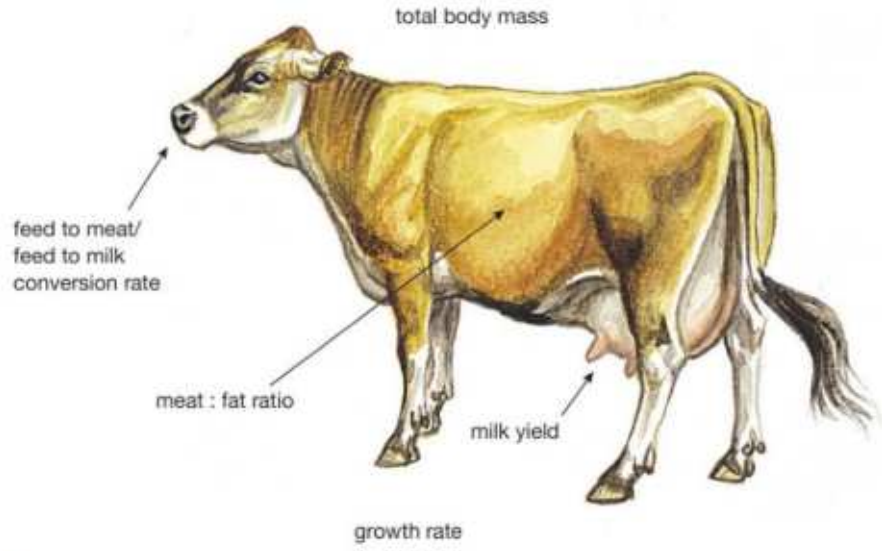
SKILLS CRITICAL THINKING

12 a How is selective breeding similar to natural selection?

b How is selective breeding different from natural selection?

SKILLS ANALYSIS

13 The diagram shows some of the features of a cow that might be used as a basis for a breeding programme.



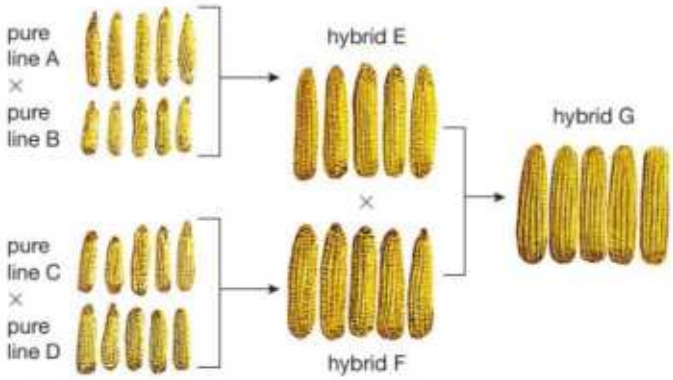
a Which features would you consider important in a breeding programme for dairy cattle?

SKILLS REASONING

b Assume that you had all the techniques of modern selective breeding available to you. Describe how you would set about producing a herd of high-yielding beef cattle.

SKILLS ANALYSIS

14 The diagram shows the results of a breeding programme to improve the yield of maize (sweetcorn).



a Describe the breeding procedure used to produce hybrid G.

b Describe three differences between the corn cobs of hybrid G and those of C.

SKILLS REASONING

c How could you show that the differences between hybrid G and hybrid C are genetic?

SKILLS INTRAPERSONAL

15 Carry out some research and write an essay about the benefits and concerns of selective breeding of animals. You should write about one side of A4.

UNIT QUESTIONS

SKILLS REASONING

1 For natural selection to operate, some factor has to exert a 'selection pressure'. In each of the following situations, identify both the selection pressure and the likely result of this selection pressure.

a Near old copper mines, the soil becomes polluted with copper ions that are toxic to most plants. **(2)**

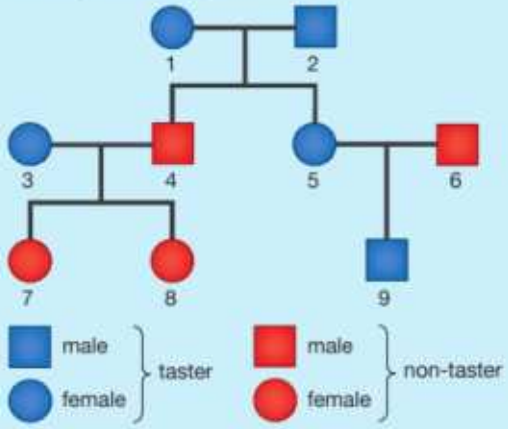
b In the Serengeti of Africa, wildebeest are hunted by lions. **(2)**

c A farmer uses a pesticide to try to eliminate pests of a potato crop. **(2)**

(Total 6 marks)

SKILLS ANALYSIS

2 PTC (phenylthiocarbamide) is a chemical that to some people has a very bitter taste, while other people cannot taste it at all. The diagram shows the inheritance of PTC tasting in a family.



a What evidence in the diagram suggests that the allele for PTC tasting is dominant? **(2)**

SKILLS REASONING

b Using T to represent the tasting allele and t to represent the non-tasting allele, give the genotypes of individuals 3 and 7. Explain how you arrived at your answers. **(4)**

SKILLS ANALYSIS

c Why can we not be sure of the genotype of individual 5? **(2)**

SKILLS INTRPRETATION

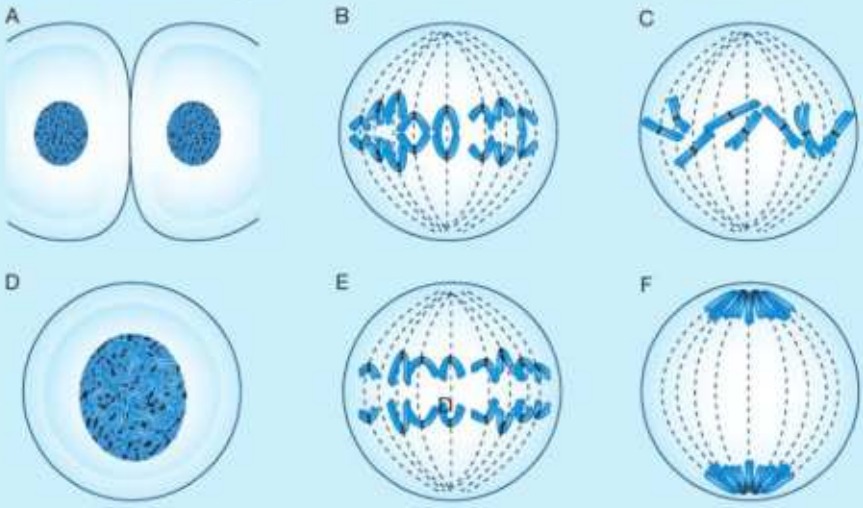
d If individuals 3 and 4 had another child, what is the chance that the child would be able to taste PTC? Construct a genetic diagram to show how you arrived at your answer. **(4)**

(Total 12 marks)

SKILLS ANALYSIS

7th

3 The diagrams A to F show an animal cell during cell division. The diploid number of this cell is eight.



a Put the pictures in the correct order. **(2)**

8th

b Is the cell going through mitosis or meiosis? Explain your answer. **(2)**

SKILLS CRITIACL THINKING

6th

c What is the diploid number of a human cell? **(1)**

7th

d Describe two differences between mitosis and meiosis. **(2)**

(Total 7 marks)

BIOLOGY UNIT 6 MICROORGANISMS AND GENETIC MODIFICATION

You have seen how some microorganisms are essential decomposers in ecosystems and recycle nutrients, while others are pathogens, causing diseases of animals and plants. There are a few species of microorganisms that are grown by humans in order to make useful products. In this unit we look at this last group, and consider traditional and modern biotechnology. In addition, microorganisms are sometimes genetically engineered to produce new products. This is described in the final chapter, along with some examples of genetically modified plants and animals.



20 USING MICROORGANISMS

In this chapter we look at microorganisms that are grown in order to make products that are of use to humans.

LEARNING OBJECTIVES

- Understand the role of yeast in the production of food, including bread
- Investigate the rate of anaerobic respiration by yeast in different conditions
- Understand the role of bacteria (*Lactobacillus*) in the production of yoghurt
- Understand the use of an industrial fermenter and explain the need to provide suitable conditions for the growth of microorganisms in the fermenter, including aseptic precautions, nutrients, optimum temperature and pH, oxygenation, and agitation

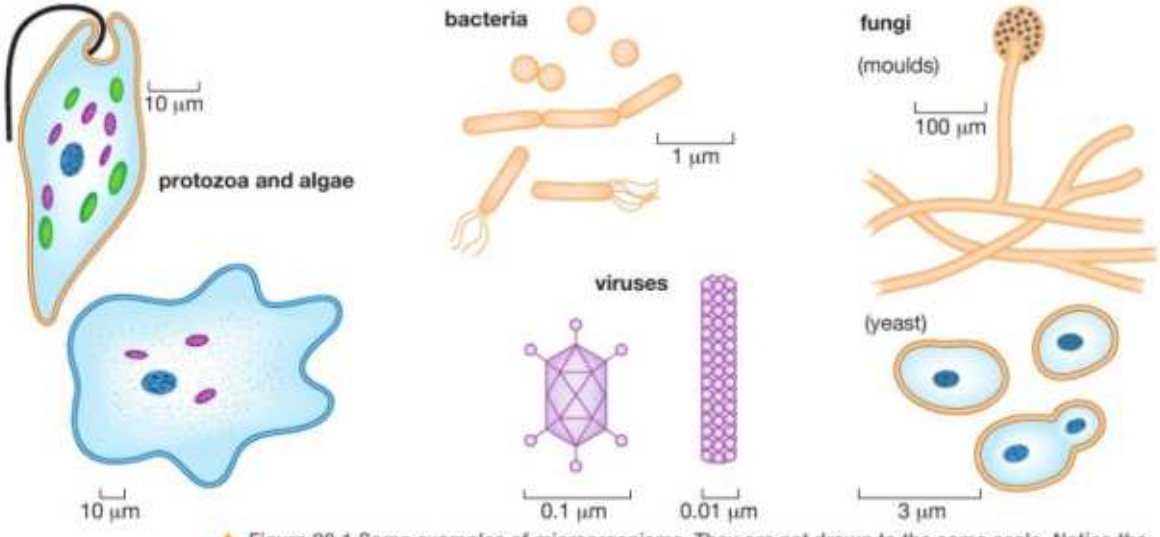
WHAT ARE MICROORGANISMS?

Microorganisms are living things that you can only see with the help of a microscope. The 'bodies' of most microorganisms are made of a single cell, although sometimes millions of cells are gathered together to form a colony. The colony of cells may then be visible to the human eye.

Microorganisms have critical roles to play in recycling the waste products of organisms, as well as recycling the organisms themselves when they die. Many types of microorganisms are studied because they cause disease in animals and plants. On the other hand, humans have made use of the great reproductive capacity of microorganisms to make useful products, such as food, drink and medicines.

There are several groups that we call microorganisms, including protoctists, bacteria, viruses and some fungi (see Chapter 2).

Figure 20.1 shows a few examples of the many types of microorganisms.



▲ Figure 20.1 Some examples of microorganisms. They are not drawn to the same scale. Notice the range of size, as shown by the scale bar alongside each organism. One micrometre (1 μm) is a millionth of a metre, or a thousandth of a millimetre.

FERMENTATION AND BIOTECHNOLOGY

Fermentation and **fermenters** are terms that you will encounter if you are involved in the growth of microorganisms. What do these words mean? Many microorganisms respire anaerobically (see Chapter 1), and originally, fermentation meant any anaerobic respiration process involving microorganisms, such as the fermentation of sugars by yeast. Nowadays, the word is used more generally to define other metabolic processes carried out by microorganisms, many of which are aerobic. Fermentation is normally used to make a useful product.

This overlaps with the definition of **biotechnology**, which means using any organisms (but mainly microbes) to make products that are useful to humans. Although the word itself is relatively new, humans have been using biotechnology processes for thousands of years without knowing it. Since ancient times, fermentation by yeast has been used to produce bread. Yoghurt is made by the action of bacteria on milk, and other bacteria and moulds are used in cheese manufacture.

Our ancestors used biotechnology to make products like these, but they did not understand *how* they were made and had no idea of the existence of microorganisms. Nowadays we understand what is happening when fermentation takes place, and can use biotechnology to produce not just foods but also a huge range of products, from medicines like penicillin to chemicals such as enzymes and fuels.

Modern biotechnology also allows us to alter the genes of microorganisms so that they code for new products. This is called **genetic engineering**. It is a topic that you will read about in Chapter 21.

TRADITIONAL BIOTECHNOLOGY – MAKING FOOD AND DRINKS

When yeast cells are deprived of oxygen, they respire anaerobically, breaking sugar down into ethanol and carbon dioxide:

glucose → ethanol + carbon dioxide

This process has been used for thousands of years to make bread using a species of yeast called *Saccharomyces cerevisiae*.

MAKING ALCOHOLIC DRINKS

Wine is made by using yeast to ferment sugars in grape juice. Commercial wine production takes place in large containers called vats which prevent air reaching the wine and ensure conditions remain anaerobic. Homemade wine is produced in small-scale fermenters fitted with an 'airlock', which allows carbon dioxide to escape but prevents the entry of oxygen (Figure 20.2). The alcohol increases in concentration until it kills the yeast cells, at which point fermentation stops.

Beer is made from barley. Barley contains starch rather than sugars so the starch needs to be broken down first. This happens by allowing the barley seeds to germinate. When they start to germinate they produce the enzyme amylase, which breaks down starch into the sugar maltose. Amylase breaks down starch into the sugar maltose. Later, the maltose from the seeds is fermented by yeast in a large open vat (Figure 20.3).



▲ Figure 20.2 A small fermenter for producing homemade wine. The U-shaped tube at the top is a water-filled airlock that prevents oxygen entering the fermenter but allows carbon dioxide to escape.



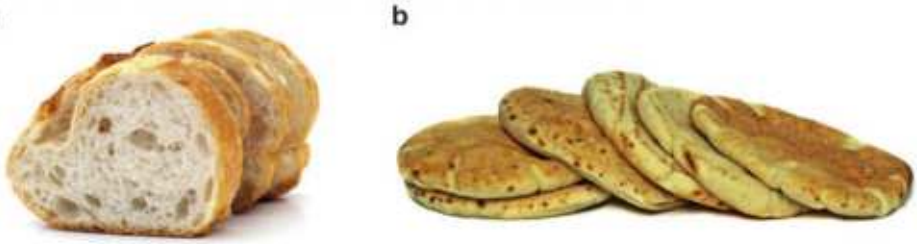
▲ Figure 20.3 A froth forming on the surface of the beer as yeast ferments the sugar to alcohol and carbon dioxide. The carbon dioxide in the froth prevents oxygen entering the mixture from the air – keeping conditions anaerobic.

MAKING BREAD

Yeast is also used to make bread. Wheat flour and water are mixed together and yeast added, forming the bread dough. Enzymes from the original cereal grains break down starch to sugars, which are respired by the yeast. Extra sugar may be added at this stage. In bread-making, the yeast begins by respiring aerobically, producing water and carbon dioxide. The carbon dioxide makes the dough rise. When the air runs out, conditions become anaerobic, so the yeast begins to respire anaerobically making ethanol and more carbon dioxide.

Later, when the dough is baked in the oven, the gas bubbles expand. This gives the bread a light, cellular texture (Figure 20.4). Baking also kills the yeast cells and evaporates any ethanol from the fermentation.

a b



▲ Figure 20.4 (a) The 'holes' in this bread were produced by bubbles of carbon dioxide released from the respiration of the yeast. (b) Bread that is made without yeast is called unleavened bread. What is the difference in texture and appearance between leavened and unleavened bread?

ACTIVITY 1

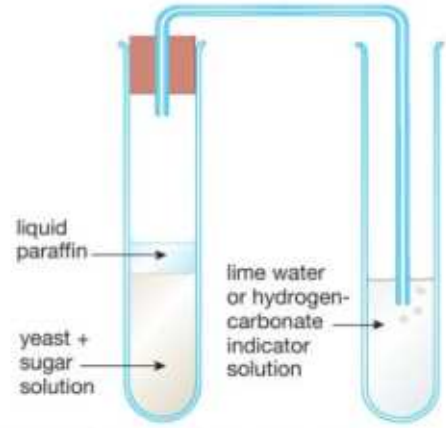
▼ PRACTICAL: INVESTIGATING THE RATE OF ANAEROBIC RESPIRATION IN YEAST

Safety note: Wear eye protection and avoid skin contact with the indicator.

Some simple apparatus and materials can be used to investigate the rate of anaerobic respiration in yeast.

A small amount of water is gently boiled in a boiling tube to remove any air that is dissolved in the water. The water is allowed to cool, and a small amount of sugar (glucose or sucrose) is dissolved in the water. Finally, a little yeast is added and the mixture is stirred.

The apparatus is set up as shown in Figure 20.5.



▲ Figure 20.5 Apparatus to test for carbon dioxide produced by anaerobic respiration in yeast.

A thin layer of liquid paraffin is added to the surface of the mixture, using a pipette. The boiled water ensures that there is no oxygen in the mixture, and the layer of paraffin stops any oxygen diffusing in from the air. A control apparatus is set up. This is exactly the same as that shown in Figure 20.5, except that boiled (killed) yeast is used instead of living yeast.

Both sets of apparatus are left in a warm place for an hour or two. The mixture with living yeast will be seen to produce gas bubbles. The gas passes through the delivery tube and into the indicator in the second boiling tube.

If this tube contains limewater, it will turn cloudy (milky). If it contains hydrogen carbonate indicator, the indicator will change from orange to yellow. This shows that the gas is carbon dioxide. The time taken for the indicator to change colour is recorded and compared with the control (which will not change).

(If the bung is taken out of the first boiling tube and the liquid paraffin removed using a pipette, the tube will smell of alcohol.)

This method can be used to test predictions, such as:

- the type of sugar (glucose, sucrose, maltose etc.) affects the rate of respiration of the yeast
- the concentration of sugar affects the rate of respiration of the yeast
- how temperature affects the rate of respiration of the yeast.

The rate can be found by timing how quickly the indicator changes colour, or from the rate of production of bubbles of carbon dioxide. You could plan experiments to test these hypotheses.

MAKING YOGHURT

Yoghurt is milk that has been fermented by certain species of bacteria, called **lactic acid bacteria**. The effect of the fermentation is to turn the liquid milk into a semi-solid food with a sour taste.

To make yoghurt, milk is first pasteurised at 85–95 °C for 15–30 minutes, to kill any natural bacteria that it contains, then homogenised to disperse the fat globules. The milk is then cooled to 40–45 °C and inoculated with a starter culture of two species of bacteria, called *Lactobacillus* and *Streptococcus*.

DID YOU KNOW?

Different species of *Lactobacillus* and *Streptococcus* bacteria are also used in the production of cheese.

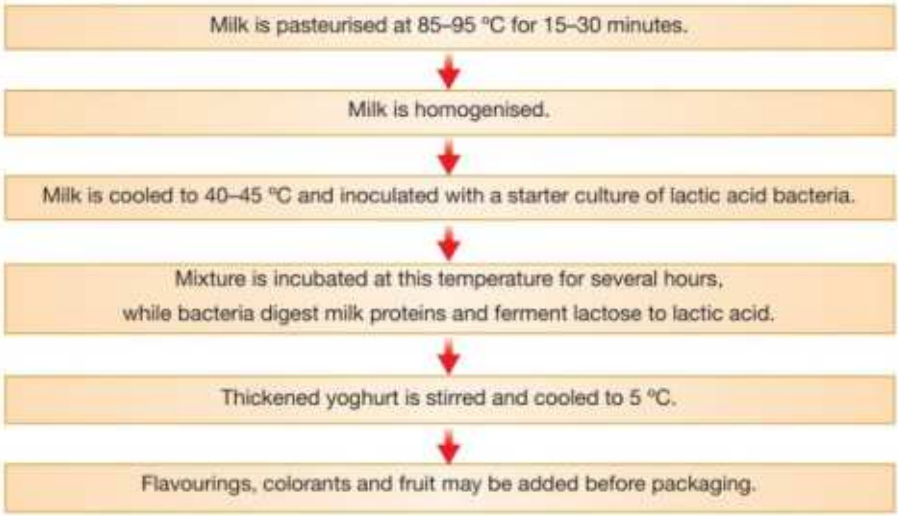
DID YOU KNOW?

The process called pasteurisation is named after the famous French microbiologist, Louis Pasteur. He was trying to find a way to kill the bacteria in beverages that caused them to go sour. In 1864 Pasteur discovered that short periods of heating killed most of the bacteria responsible for this 'spoilage', without affecting the quality. Today, pasteurisation is used to treat many products, such as milk, fruit juices and canned food.

These bacteria produce lactic acid, as well as starting to digest the milk proteins. The culture is kept at this temperature for several hours while the pH falls to about 4.4 (these are the optimum conditions for the bacteria). The mixture coagulates (thickens) as the drop in pH causes the milk proteins to denature and turn into semi-solids.

When fermentation is finished, the yoghurt is stirred and cooled to 5 °C. Flavourings, colourants and fruit may then be added before it is packaged for sale.

The drop in pH (as the yoghurt forms) gradually reduces the reproduction of the lactic acid bacteria (although it doesn't kill them). It also helps to prevent the growth of other microorganisms, and so preserves the nutrients in the milk. The steps in yoghurt production are summarised in the flow chart (Figure 20.6).



▲ Figure 20.6 Flow chart showing the stages in yoghurt production.

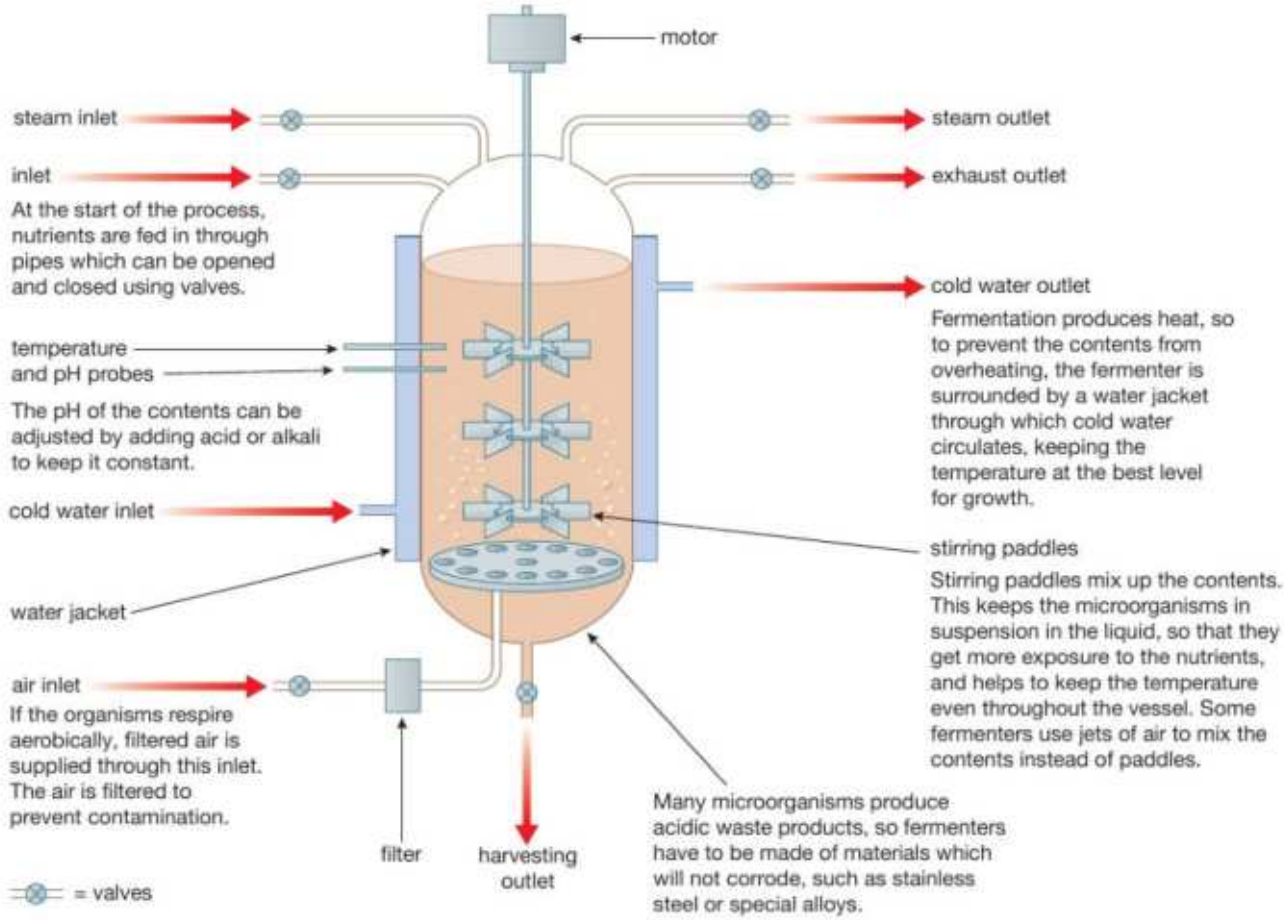
INDUSTRIAL FERMENTERS



A **fermenter** is any vessel that is used to grow microorganisms used for fermentation. Even a baking tray containing a ball of dough could be defined as a fermenter!

Industrial fermenters are large tanks that can hold up to 200 000 dm^3 of a liquid culture (Figure 20.7). They enable the environmental conditions such as temperature, oxygen and carbon dioxide concentrations, pH and nutrient supply to be carefully controlled so that the microorganisms will yield their product most efficiently. A simplified diagram of the inside of a fermenter is shown in Figure 20.8.

◀ Figure 20.7 An industrial fermenter holds hundreds of thousands of dm^3 of a liquid culture.



▲ Figure 20.8 An industrial fermenter. Fermenters like this are used to make many products, such as the antibiotic penicillin.

KEY POINT

Many microorganisms use an external food source from their growth medium to obtain energy. In doing this, they change substances in the medium. This is the modern meaning of fermentation. It is used by humans to make many important products. The use of microorganisms to make products useful to humans is called biotechnology.

When fermentation is completed, the products are collected through an outlet pipe. Before the fermenter is filled with new nutrients and culture, the inside of the tank and all the pipes must be cleaned and sterilised. This is usually done with very hot steam under high pressure.

If the inside of the fermenter and the new nutrients are not sterile, two problems are likely to develop. Firstly, any bacteria or fungi that manage to get in would compete with the organism in the culture, reducing the yield of product. Secondly, the product would become contaminated with waste products or cells of the 'foreign' organism. The methods used to prevent contamination by unwanted microorganisms such as filtering the air and sterilising the fermenter using steam, are known as 'aseptic precautions'.

CHAPTER QUESTIONS

More questions on growing useful organisms can be found at the end of Unit 6 on page 256.

SKILLS CRITICAL THINKING

1 Which of the following is *not* normally controlled in an industrial fermenter?

A Temperature **B** Light intensity **C** pH **D** Oxygen

2 During the manufacture of yoghurt, the pH of the milk changes. What causes this change in pH?

A denaturing of the milk proteins

B pasteurisation of the milk

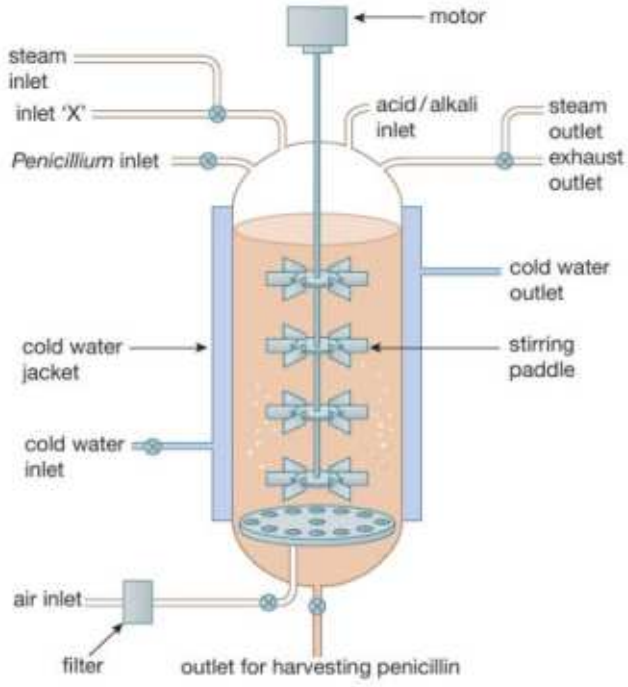
C the conversion of lactose into lactic acid

D yhe action of an enzyme in the milk

3 Yoghurt can be made at home by adding a small amount of old yoghurt to some fresh milk. What is present in the old yoghurt to cause this to happen?

A fat **B** sugar **C** protein **D** bacteria

4 The diagram shows an industrial fermenter which is used to grow the mould *Penicillium* to make the antibiotic penicillin.



a Explain how the fermenter is sterilised before use.

SKILLS REASONING

b Why does air need to be pumped through the fermenter? Why is the air filtered?

SKILLS REASONING

c Explain how a steady temperature is maintained in the fermenter.

d What is supplied through the inlet marked 'X'?

e Suggest what would happen to the growth of *Penicillium* in the fermenter if the paddles stopped working.

SKILLS CRITICAL THINKING



5 Answer these questions about making yoghurt. Try at first to answer them without looking back to the section on page 241.

a Why is the milk pasteurised at the start of the process?

b Why is the mixture of milk and bacteria incubated at 45 °C?

c What causes the milk to thicken?

d Why does fermentation eventually stop?

e Explain how making yoghurt is a way of preserving the nutrients from milk.

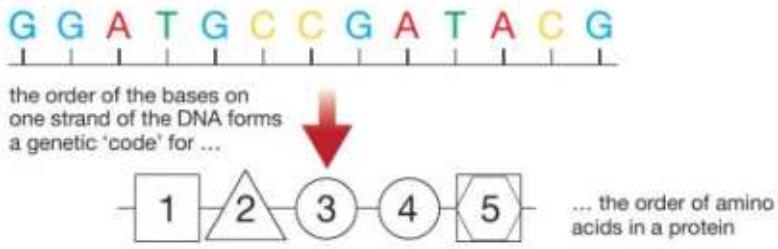
21 GENETIC MODIFICATION

In this chapter we will look at ways in which it is now possible to manipulate genes and produce genetically modified organisms – the science of 'genetic engineering'.

LEARNING OBJECTIVES

- Understand that the term 'transgenic' means the transfer of genetic material from one species to a different species
- Understand how restriction enzymes are used to cut DNA at specific sites and ligase enzymes are used to join pieces of DNA together
- Understand how plasmids and viruses can act as vectors, which take up pieces of DNA, and then insert this recombinant DNA into other cells
- Understand how large amounts of human insulin can be manufactured from genetically modified bacteria that are grown in a fermenter
- Understand how genetically modified plants can be used to improve food production

In Chapter 16 you saw that a gene is a section of a molecule of DNA that codes for the production of a protein. One strand of the DNA (called the coding strand) contains triplets of bases, each triplet coding for one amino acid. Different genes produce different proteins because each has a unique sequence of bases that codes for a unique sequence of amino acids (Figure 21.1).



▲ Figure 21.1 The role of DNA in protein synthesis

The protein that is produced could be:

- an enzyme that controls a particular reaction inside a cell or in the digestive system
- a structural protein like keratin in hair, collagen in skin or one of the many proteins found in the membranes of cells
- a protein hormone such as insulin
- a protein with a specific function such as haemoglobin or an **antibody**.

KEY POINT

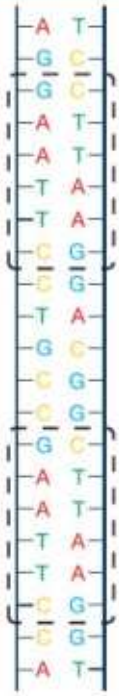
A transgenic organism is one that contains a gene that has been introduced from another species. For example, some bacteria have had human genes transferred to them that allow them to make human insulin. Some sheep secrete the protein alpha-1-antitrypsin (AAT) in their milk because they have the human gene that directs the manufacture of this substance. Because they contain 'foreign' genes, they are no longer quite the same organisms. They are transgenic.

RECOMBINANT DNA

The production of **recombinant DNA** is the basis of genetic engineering. A section of DNA – a gene – is cut out of the DNA of one species and inserted into the DNA of another. This new DNA is called 'recombinant' DNA because the DNA from two different organisms has been 'recombined'. The organism that receives the gene from a different species is a **transgenic** organism.

The organism receiving the new gene now has an added capability. It will manufacture the protein that the new gene codes for. For example, a bacterium receiving the human gene that codes for insulin production will make human insulin. If these transgenic bacteria are cultured by the billion in a fermenter, they become a factory for making human insulin.

PRODUCING GENETICALLY MODIFIED (TRANSGENIC) BACTERIA



▲ Figure 21.2 Part of a DNA molecule containing the base sequence G-A-A-T-T-C. Notice that the sequence is present on both strands, but running in opposite directions.

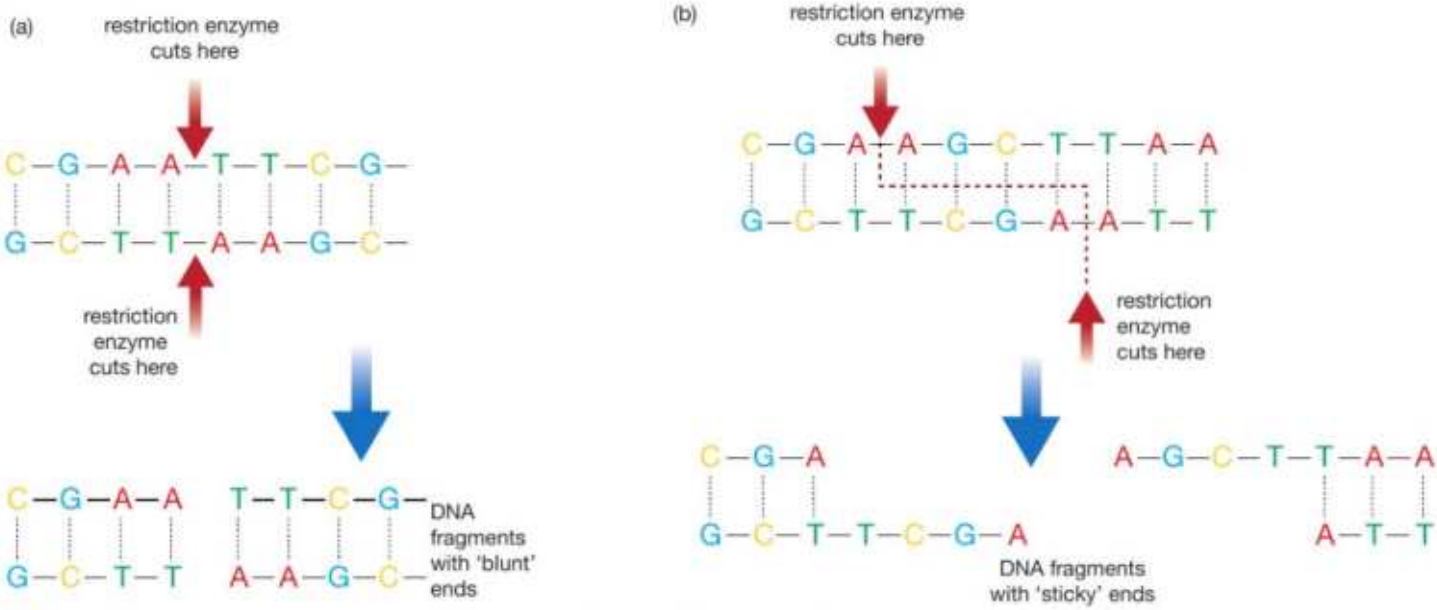
The breakthrough in being able to transfer DNA from cell to cell came when it was found that bacteria have two sorts of DNA – the DNA found in their bacterial 'chromosome' and much smaller circular pieces of DNA called **plasmids** (see Unit 1, Figure 2.10).

Bacteria naturally 'swap' plasmids, and biologists found ways of transferring plasmids from one bacterium to another. The next stage was to find molecular 'scissors' and a molecular 'glue' that could cut out genes from one molecule of DNA and stick them back into another. Further research found the following enzymes that were able to do this.

- **Restriction endonucleases** (usually shortened to **restriction enzymes**) are enzymes that cut DNA molecules at specific points. Different restriction enzymes cut DNA at different places. They can be used to cut out specific genes from a molecule of DNA.
- **Ligases** (or DNA ligases) are enzymes that join the cut ends of DNA molecules.

Each restriction enzyme recognises a certain base sequence in a DNA strand. Wherever it encounters that sequence, it will cut the DNA molecule. Suppose a restriction enzyme recognises the base sequence G-A-A-T-T-C. It will only cut the DNA molecule if it can 'see' the base sequence on both strands. Figure 21.3 illustrates this.

Some restriction enzymes make a straight cut and the fragments of DNA they produce are said to have 'blunt ends' (Figure 21.3(a)). Other restriction enzymes make a staggered cut. These produce fragments of DNA with overlapping ends with complementary bases. These overlapping ends are called 'sticky ends' because fragments of DNA with exposed bases are more easily joined by ligase enzymes (Figure 21.3(b)).

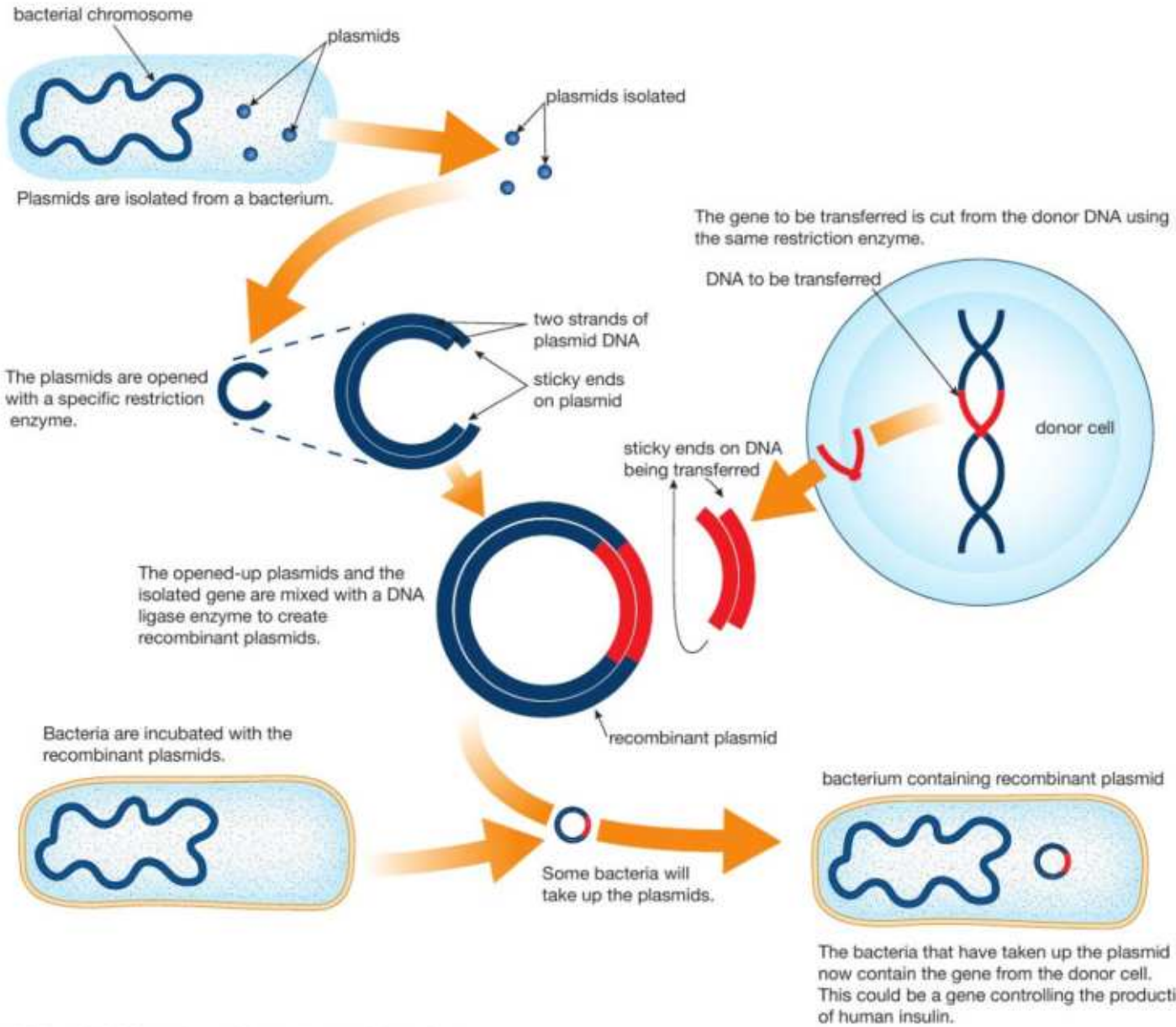


▲ Figure 21.3 How restriction enzymes cut DNA. (a) Forming blunt ends. (b) Forming sticky ends.

EXTENSION WORK

There is a lot more to producing recombinant DNA and transgenic bacteria than is shown here. You could carry out an some research to find out more about this topic.

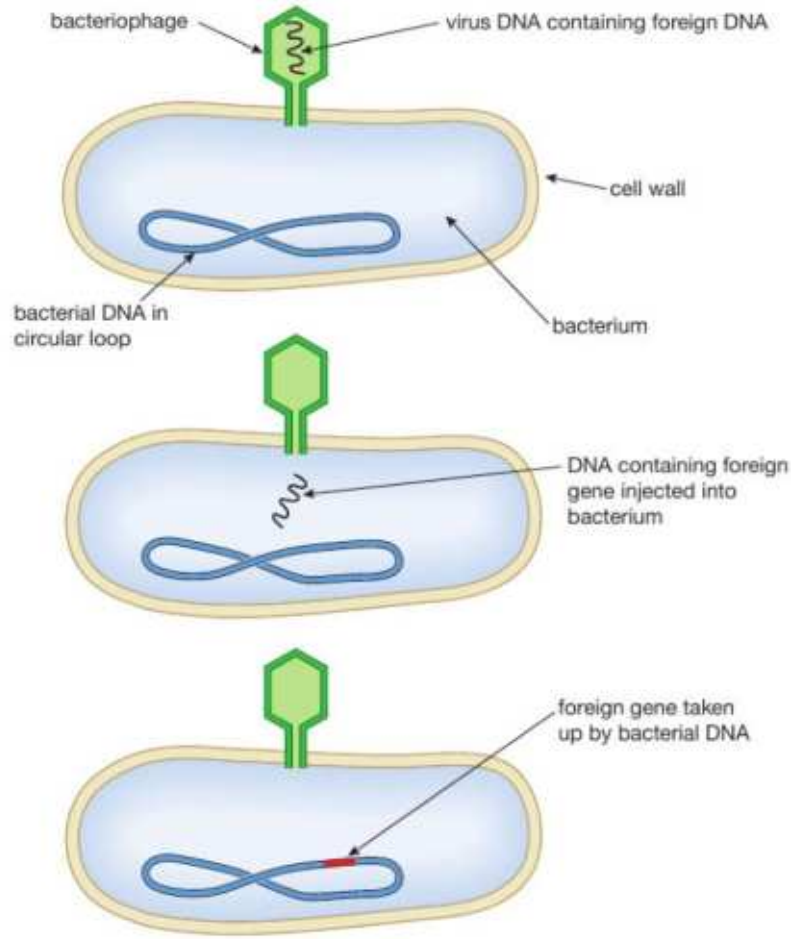
Biologists now had a method of transferring a gene from any cell into a bacterium. They could insert the gene into a plasmid and then transfer the plasmid into a bacterium. The plasmid is called a **vector** because it is the means of transferring the gene. The main processes involved in producing a transgenic bacterium are shown in Figure 21.4.



▲ Figure 21.4 Stages in producing a transgenic bacterium.

Another vector that has been used to introduce foreign DNA into bacterial cells is the **bacteriophage**. A bacteriophage, or 'phage', is a virus that attacks a bacterium. It does this by attaching to the cell wall of the bacterium and injecting its own DNA into the bacterial cell (Figure 21.5). This DNA becomes incorporated into the DNA of the host cell, and eventually causes the production of many virus particles.

If a foreign gene can be inserted into the DNA of the virus, the virus will inject it into the bacterium along with its own genes. Viruses were used as vectors in the early days of genetic modification, but most gene transfer is now carried out using plasmids.



▲ Figure 21.5 A bacteriophage attacking a bacterial cell.

MAKING USE OF GENETICALLY MODIFIED BACTERIA

Different bacteria have been genetically modified to manufacture a range of products. Once they have been genetically modified, they are cultured in fermenters to produce large amounts of the product (see Chapter 20). Some examples are described below.

DID YOU KNOW?

More insulin is required every year because the number of diabetics increases worldwide each year and diabetics now have longer life spans.

1. **Human insulin** People suffering from diabetes need a reliable source of insulin. Before the use of genetic engineering to make human insulin, the only insulin available was extracted from the pancreases of other animals such as cattle or pigs. This is not quite the same as human insulin and does not give the same level of control of blood glucose levels.

2. **Enzymes for washing powders** Many stains on clothing are biological. Blood stains are largely proteins, grease marks are largely lipids. Enzymes can digest these large, insoluble molecules into smaller, soluble ones. These then dissolve in the water. Amylases digest starch, proteases digest proteins and lipases digest lipids. Bacteria have been genetically engineered to produce enzymes that work at higher temperatures, allowing even faster and more effective action.

3. **Enzymes in the food industry** One bacterial enzyme used in the food industry is glucose isomerase. This enzyme catalyses a reaction which converts glucose into a similar sugar called fructose. Fructose is much sweeter than glucose and so less is needed to sweeten foods. This has two advantages – it saves money (since less is used) and it means that the food contains less sugar and is healthier.

4. **Human growth hormone** The pituitary gland of some children does not produce enough of this hormone and they show a slow rate of growth. Injections of growth hormone from genetically modified bacteria restore normal growth patterns.

5. **Bovine somatotrophin** *(BST)* (a growth hormone in cattle) This hormone increases the milk yield of cows and increases the muscle (meat) production of bulls. Giving injections of BST to dairy cattle can increase the milk yield by up to 10 kg per day. To do this they need more food, but this increased cost is more than offset by the increased income from the increased milk yield (Table 21.1).

6. **Human vaccines** Bacteria have been genetically modified to produce the antigens of the hepatitis B virus. This is used in the vaccine against hepatitis B. The body makes antibodies against the antigens but there is no risk of contracting the actual disease from the **vaccination**.

DID YOU KNOW?

Before human growth hormone from genetically modified bacteria was available, the only source of the hormone was from human corpses. This was a rather gruesome procedure and had health risks. A number of children treated in this way developed Creutzfeld–Jacob disease (the human form of 'mad cow' disease). When this became apparent, the treatment was withdrawn.

Table 21.1 Effects of BST on milk yield.

	Feed / kg per day	Milk output / kg per day	Milk to feed ratio
without BST	34.1	27.9	0.82
with BST	37.8	37.3	0.99

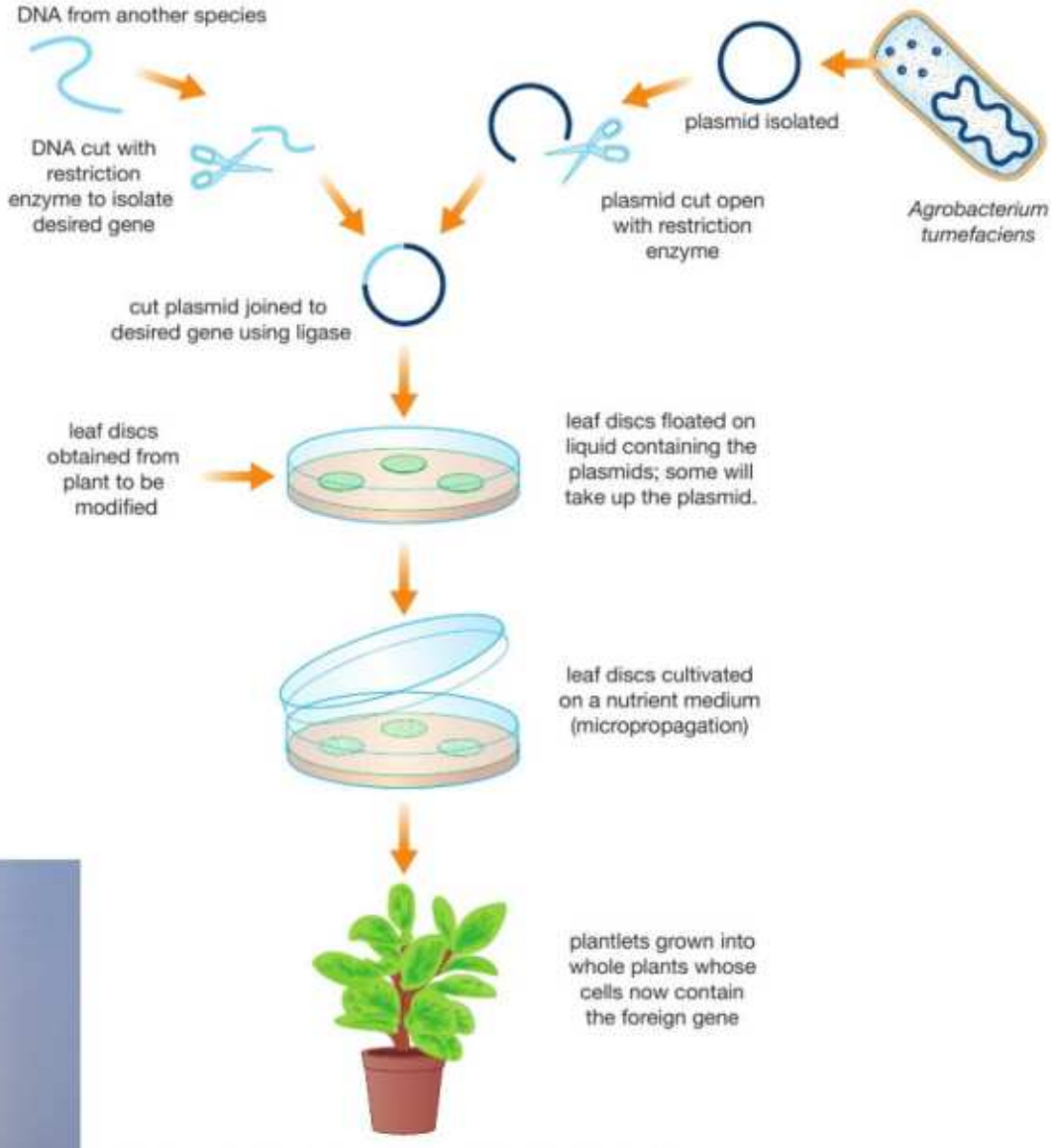
Since the basic techniques of transferring genes were developed, many unicellular organisms have been genetically modified to produce useful products. Techniques for transferring genes into plants and animals have also been developed.

PRODUCING GENETICALLY MODIFIED PLANTS

The gene technology described so far can transfer DNA from one cell to another cell. In the case of bacteria, this is fine – a bacterium only has one cell. But plants have billions of cells and to genetically modify a plant, each cell must receive the new gene. So, any procedure for genetically modifying plants has two main stages:

- introducing the new gene or genes into plant cells
- producing whole plants from just a few cells.

Biologists initially had problems in inserting genes into plant cells. They then discovered a soil bacterium called *Agrobacterium*, which regularly inserts plasmids into plant cells. Now that a vector had been found, the rest became possible. Figure 21.6 outlines one procedure that uses *Agrobacterium* as a vector.



▲ Figure 21.6 Genetically modifying plants using *Agrobacterium*.



▲ Figure 21.7 A gene gun

This technique cannot be used on all plants. *Agrobacterium* will not infect cereals and so another technique was needed for these. The 'gene gun' was invented. This is, quite literally, a gun that fires a golden bullet (Figure 21.7). Tiny pellets of gold are coated with DNA that contains the desired gene. These are then 'fired' directly into plant tissue. Research has shown that if young, delicate tissue is used, there is a good uptake of the DNA. The genetically modified tissue can then be grown into new plants using the same **micropropagation** techniques as those used in the *Agrobacterium* procedure. The gene gun has made it possible to genetically modify many cereal plants as well as tobacco, carrot, soybean, apple, oilseed rape, cotton and many others. There is, however, much debate about the rights and wrongs of GM crops. You may like to carry out some further research on this topic.

MAKING USE OF GENETICALLY MODIFIED PLANTS

Large numbers of genetically modified plants are already available to plant growers and farmers.

Some fruit and vegetables have been engineered to have extended 'shelf lives' – they last longer before they start to go bad. Other crop plants have



▲ Figure 21.8 Golden rice

EXTENSION WORK

Golden rice sounds like a good idea, but there have been several problems with it. Some people believe that there are ethical and environmental reasons why golden rice should not be grown and that it is better to provide other, natural crops containing enough beta-carotene. You could carry out some research into the advantages and disadvantages of golden rice.

KEY POINT

What if you could receive a 'vaccination' every time you ate a banana? Scientists are researching the possibility of transferring the genes that produce the antigens for certain diseases to bananas. If they succeed, then when you eat the banana, the antigens will stimulate an immune response. There will be no risk of you catching the disease – and no need to have needles stuck in you!

been modified to be resistant to herbicides (weedkillers). This allows farmers to spray herbicides at times when they will have maximum effect on the weeds, without affecting the crop plant.. There are concerns that this will encourage farmers to be less careful in their use of herbicides. In another example, genes from Arctic fish that code for an 'anti-freeze' in their blood have been transferred to some plants to make them frost resistant.

The gene gun allowed biologists to produce genetically modified rice called 'golden rice' (Figure 21.8). This rice has three genes added to its normal DNA content. Two of these come from daffodils and one from a bacterium. Together, these genes allow the rice to make beta-carotene – the chemical that gives carrots their colour. It also colours the rice, hence the name 'golden rice'. More importantly, the beta-carotene is converted to vitamin A when eaten. This could save the eyesight of millions of children in less economically developed countries, who go blind because they do not have enough vitamin A in their diet.

Genetically modified plants are also helping humans to resist infection. Biologists have succeeded in modifying tobacco plants and soybeans to produce antibodies against a range of infectious diseases. If these can be produced on a large scale, they could be given to people who are failing to produce their own antibodies. Other modified tobacco plants produce the hepatitis B antigens that could be used as the basis for a vaccine. There is always a risk with a vaccine containing viruses that they may somehow become infectious again. This could not happen with a vaccine containing only plant-produced antigens.

Besides the specific examples given, research into the genetic modification of plants provides, or hopes to provide, plants with:

- increased resistance to a range of pests and pathogens
- increased heat and drought tolerance
- increased salt tolerance
- a better balance of proteins, carbohydrates, lipids, vitamins and minerals.

In addition, some genetically modified oilseed rape plants will be used in large-scale production of biodegradable plastics and anti-coagulants.

One of the biggest achievements would be to modify crop plants like cereals and potatoes to allow nodules of nitrogen-fixing bacteria to form on their roots. At the moment only legumes (peas, beans and other plants with seeds in 'pods') can do this. Biologists know that the ability is genetically controlled. So far, they have not been able to transfer these genes to other plants. If they could, vast areas of infertile soil would be able to yield good crops of cereals without the need to use large quantities of fertilisers.

The bacteria in the **root nodules** would obtain nitrogen from the air in the soil and 'fix' it in a more usable form (usually ammonia). By doing this, they would make a supply of usable nitrogen available to the plants. The plants would convert this into plant protein and use the protein for growth. The cost of producing these crops would decrease dramatically.

PRODUCING GENETICALLY MODIFIED ANIMALS

Producing genetically modified animals presents some of the same problems as those connected with modifying plants. Animals, like plants, are multicellular. It is not enough simply to transfer a gene to a cell. That cell must then grow into a whole organism. The plasmid technology used to create

DID YOU KNOW?

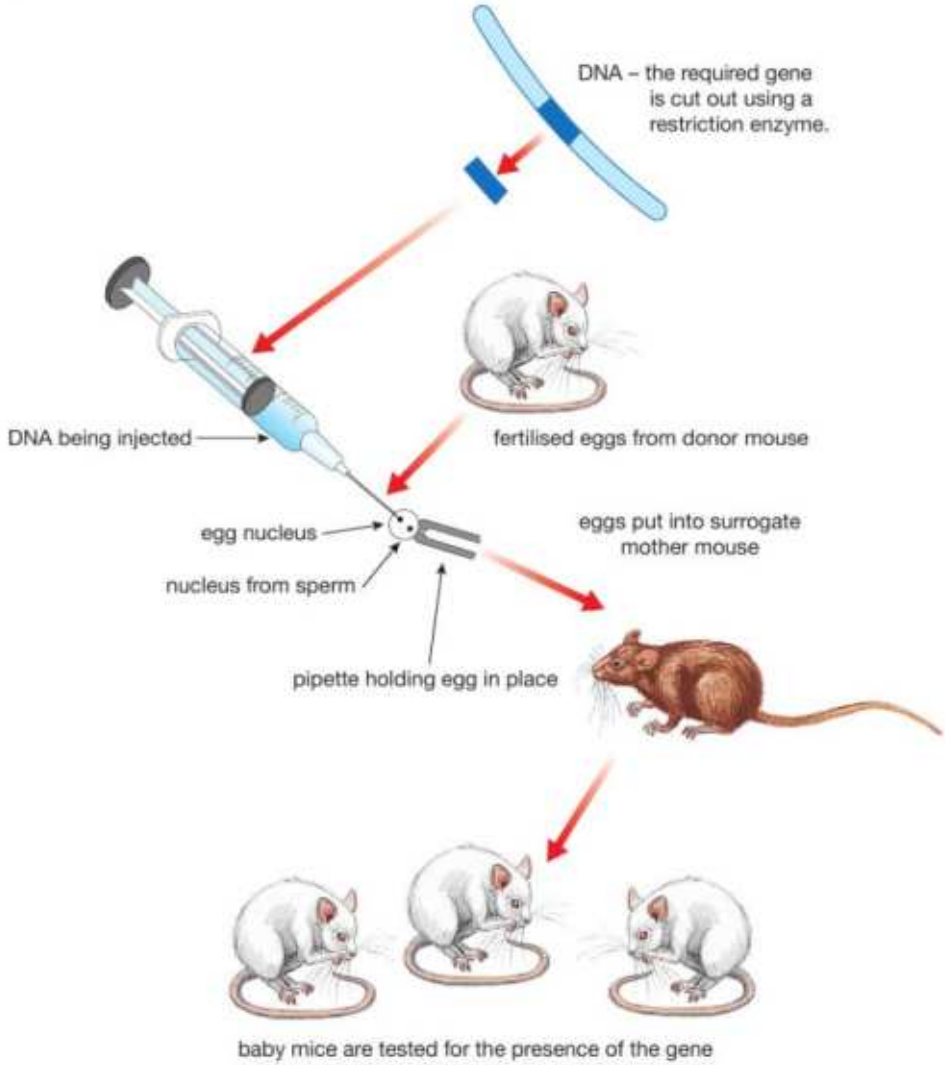
'Xenotransplantation' means transplanting organs from other animals into humans. Transgenic pigs have been produced with genes that code for the main human 'marker antigens'. The cells of the pig's organs therefore have these human antigens on their surface and the organs would be less likely to be rejected by a recipient. If this became possible on a large scale, it could help to overcome the shortage of donor organs for transplantation. However, many people have ethical concerns about using animal organs for transplanting into humans.

genetically modified plants depends on the modified cells being grown into whole plants using micropropagation. No such micropropagation techniques exist for animals.

Scientists researching the production of genetically modified animals had to find other techniques. The most successful involves injecting DNA directly into a newly fertilised egg cell. This develops into an embryo, then an adult (Figure 21.9).

Research of this kind can produce beneficial results similar to those achieved by genetically modifying plants, such as:

- manufacture of human proteins, such as antibodies, blood clotting factors or alpha-1-antitrypsin (AAT) – see below
- increased production of a particular product, e.g. higher milk yield in cows, greater muscle mass in animals used for meat
- increased resistance to disease
- production of organs for transplantation (xenotransplantation).

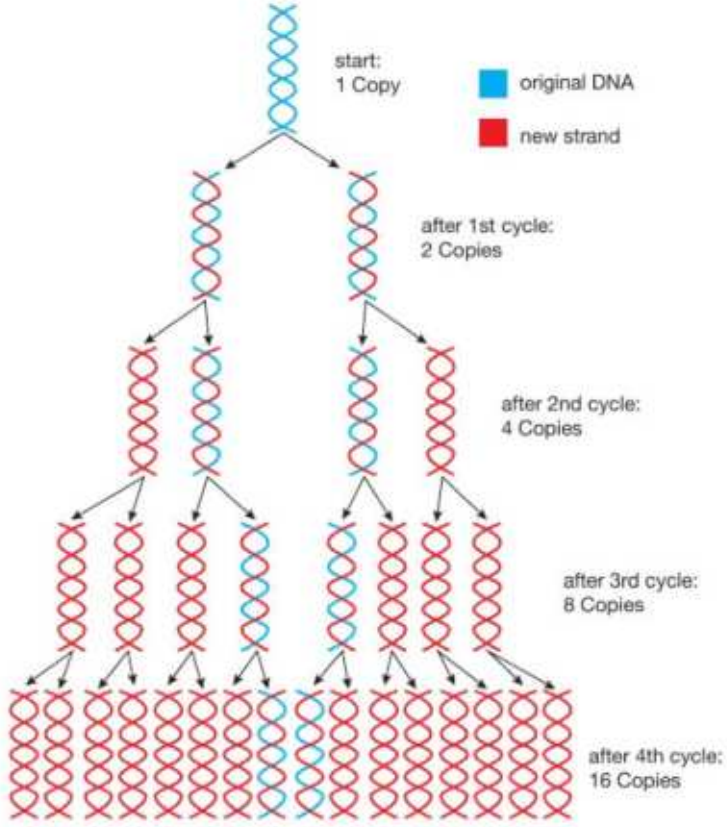


▲ Figure 21.9 The procedures used in producing genetically modified animals.

LOOKING AHEAD – THE POLYMERASE CHAIN REACTION

The polymerase chain reaction (PCR) is a laboratory process that amplifies DNA. This means that it rapidly produces a large number of copies of a piece of DNA, starting from as little as one molecule. The invention of PCR revolutionised gene technology and is used in virtually every application of the science.

Each cycle of PCR doubles the amount of DNA, producing an exponential increase in the numbers of copies (Figure 21.10). Thirty cycles produces over a billion copies of the original DNA.



▲ Figure 21.10 PCR produces an exponential increase in the number of copies of a piece of DNA.

The procedure uses short lengths of single-stranded DNA called primers, which are precisely complementary to one end of each strand of the DNA you wish to amplify. The DNA is heated to separate the strands and the primers added to the ends of each strand. An enzyme called DNA polymerase builds up two new complimentary strands by adding nucleotides - one at a time - along each strand.

Nowadays, PCR is an automated process and can be performed in as little as 2–3 hours in a PCR machine. You just place small tubes containing the DNA sample, primers, free nucleotides, DNA polymerase and a buffer solution in the machine, switch on, and wait for the results.

CHAPTER QUESTIONS

More questions on gene technology can be found at the end of Unit 6 on page 256.

SKILLS CRITICAL THINKING

1 Why is it relatively easy to genetically modify bacteria?

A they reproduce slowly and accurately

B they are able to take up plasmids

C they only contain a single chromosome

D they make restriction enzymes

2 The statements below show some stages in the production of human insulin from genetically modified bacteria.

1. DNA for insulin inserted into plasmids
2. bacteria cloned
3. plasmids inserted into bacteria
4. DNA for insulin cut out using restriction enzyme

Which of the following shows the correct sequence of steps in the process?

A 2 → 1 → 4 → 3

B 4 → 2 → 3 → 1

C 4 → 1 → 3 → 2

D 2 → 3 → 4 → 1

3 Which of the following genetically modified plants have not been produced yet?

A rice that is rich in beta-carotene to make vitamin A

B plants resistant to weedkiller

C plants containing an anti-freeze

D cereals with nitrogen-fixing bacteria in root nodules

4 Which of the following enzymes is used to join together pieces of DNA?

A ligase

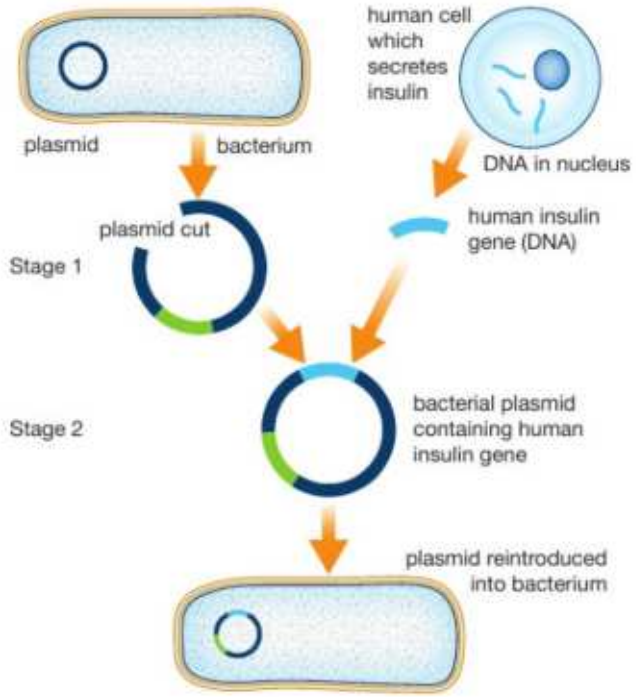
B DNA polymerase

C protease

D restriction enzyme

SKILLS ANALYSIS

5 The diagram shows the main stages in transferring the human insulin gene to a bacterium.



a Name the enzymes used at stages 1 and 2.

SKILLS CRITICAL THINKING

b What is the role of the plasmid in this procedure?

c How would the insulin-producing bacteria be used to produce significant amounts of insulin?

SKILLS REASONING

d Why is the insulin produced this way preferred to insulin extracted from other animals?

SKILLS INTRAPERSONAL

6 Carry out some research to find out more about the use of transgenic animals for organ transplantation. What are the arguments for and against its use? What are the ethical objections?

SKILLS CRITICAL THINKING

7 Producing genetically modified plants and animals is more complex than producing genetically modified bacteria.

a Describe two ways in which genes can be introduced into plant cells.

b How are these genetically modified cells used to produce whole organisms?

c What sort of animal cell is genetically modified and then used to produce the whole organism?

SKILLS INTRAPERSONAL

8 Write an essay about the importance of genetic engineering. In your essay you should make reference to:

a important potential benefits resulting from genetic engineering in animals and plants

b concerns about the risks resulting from genetic engineering in animals and plants.

UNIT QUESTIONS

SKILLS CRITICAL THINKING

1 Some experimental sheep were genetically modified, using a human gene. The gene codes for a protein involved in blood clotting, called factor IX.

The gene for factor IX was cut from human DNA and injected into a sheep body cell. The nucleus of this body cell was transferred to an enucleated sheep ovum. The ovum was cultured in a dish and then implanted in the uterus of a surrogate sheep to complete its development.

Two lambs produced by this method grew to maturity. They produced milk from which Factor IX could be extracted.

a Name an enzyme that can be used to cut DNA. **(1)**

b What is an *enucleated ovum*? **(2)**

c The sheep produced by this method are called *transgenic*. What is meant by this term? **(1)**

SKILLS REASONING

d The transgenic sheep were reproduced by *cloning*. What are the advantages of producing the sheep in this way? **(3)**

e Factor IX can be used to treat people with a blood clotting disorder called haemophilia. Why is important to have blood that clots? **(2)**

SKILLS CRITICAL THINKING

f Blood contains plasma, white blood cells, red blood cells and platelets. Which *two* components of the blood are involved with blood clotting? **(2)**

(Total 11 marks)

2 Some genes are transferred from one plant species to another. These genes are called 'jumping genes'. Environmentalists are concerned that genetically modified plants may transfer some of their genes to wild species. Explain their concern about genetically modified plants that:

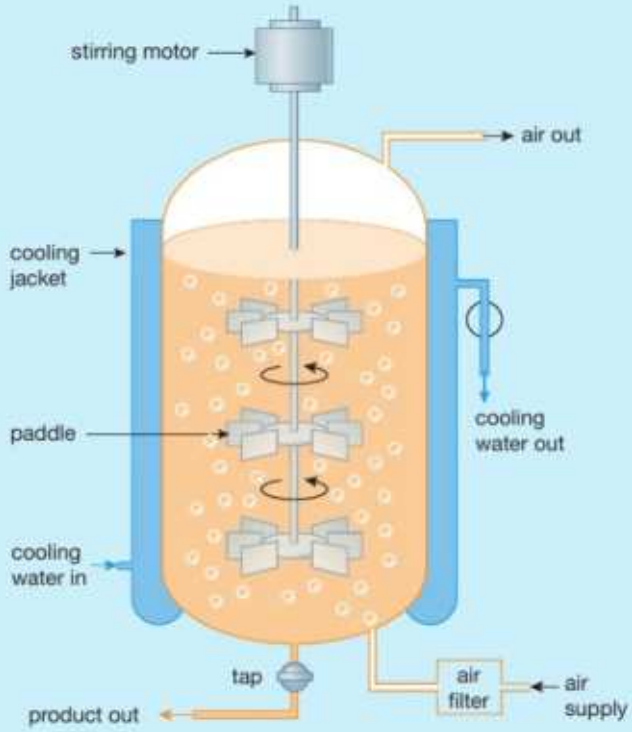
a have genes that make them resistant to herbicides (weedkillers) **(2)**

b have genes that make them resistant to pests **(2)**

c have genes that increase the yield of the crop they can produce. **(2)**

(Total 6 marks)

SKILLS REASONING 6th **3** The diagram shows a fermenter of the type used to grow microorganisms used to produce human insulin. Insulin is used to treat people with diabetes.



a Explain why air is pumped through the fermenter. **(2)**

b Why is it necessary to keep the temperature in the fermenter constant? **(2)**

7th **c** Suggest one other condition that must be kept constant inside the fermenter. **(1)**

d The fermenter is sterilised by steam. Suggest why this is better than using disinfectants. **(2)**

9th **e** Insulin can also be obtained from animal pancreases. Suggest two advantages of using microorganisms to produce the insulin needed by diabetics. **(2)**

(Total 9 marks)

SKILLS CRITICAL THINKING 8th **4**

a Explain the meaning of the following terms:
- **i** a plasmid
- **ii** a bacteriophage. **(6)**

9th **b** Explain the importance of the following enzymes in genetic engineering:
- **i** restriction enzymes
- **ii** ligase enzymes. **(6)**

(Total 12 marks)

STATES OF MATTER 259 | ELEMENTS, COMPOUNDS AND MIXTURES 266 | ATOMIC STRUCTURE 276
THE PERIODIC TABLE 282 | CHEMICAL FORMULAE, EQUATIONS AND CALCULATIONS 290
IONIC BONDING 316 | COVALENT BONDING 326

CHEMISTRY UNIT 1 PRINCIPLES OF CHEMISTRY

The universe is made of three things!

Up to the present day scientists have discovered 118 elements. Most of these have been made naturally in stars but some are made artificially. As far as we know these are the only elements in the universe, so we basically have a model kit containing 118 different atoms. Chemistry can be described as the study of how these different atoms are joined together in various ways to make everything around us, from a tree, to a person, to the tallest skyscraper. Many of these elements are not very common so most of the things we see around us are made up of different combinations of only about a quarter of these elements. What makes this even more amazing is that each atom is made up of just three subatomic particles, which are called protons, neutrons and electrons. So, the world around us is made of only three things arranged in different ways.



1 STATES OF MATTER

Everything around us is made of particles that we can't see because they are so small. This chapter looks at the arrangement of particles in solids, liquids and gases, and the ways in which the particles can move around. The nature of the different sorts of particles will be explored in Chapter 3.



▲ Figure 1.1 Everything you look at is a solid, a liquid or a gas . . .



▲ Figure 1.2 . . . metals, concrete, water, air, clouds – everything!

LEARNING OBJECTIVES

- Understand the three states of matter in terms of the arrangement, movement and energy of the particles
- Understand the interconversions between the three states of matter in terms of:
  - the names of the interconversions
  - how they are achieved
  - the changes in arrangement, movement and energy of the particles
- Understand how the results of experiments involving the dilution of coloured solutions and diffusion of gases can be explained
- Know what is meant by the terms:
  - solvent
  - solute
  - solution
  - saturated solution

STATES OF MATTER

Solids, liquids and gases are known as the three states of matter.

THE ARRANGEMENT OF THE PARTICLES

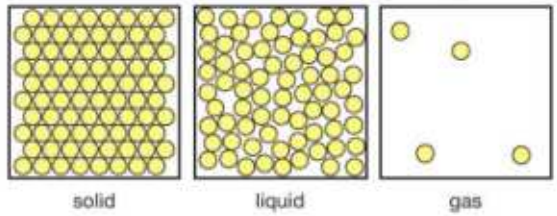
Think about these facts:

- You can't walk through a brick wall, but you can move (with some resistance – it pushes against you) through water. Moving through air is easy.
- When you melt most solids their volume increases slightly. Most liquids are less dense than the solid they come from.
- If you boil about 5 cm^3 of water, the steam will fill an average bucket.

HINT

The packing in the solid might be completely different. What is important is that the particles are close together and, usually, regularly packed. When you draw a liquid, make sure the particles are mostly touching the particles next to them.

The arrangement of the **particles** in solids, liquids and gases explains these facts.



▲ Figure 1.3 The arrangement of particles in different states of matter

KEY POINTS

- You can't walk through a brick wall because of the strong forces of attraction between the particles – the particles can't move out of your way.
- You can swim through water because you can push the particles out of the way.
- It is easy to move through a gas because there are no forces between the particles.

In a solid, the particles are usually arranged regularly and packed closely together. The particles are only able to vibrate about fixed positions; they can't move around. The particles have strong forces of attraction between them, which keep them together.

In a liquid, the particles are still mostly touching, but some gaps have appeared. This is why liquids are usually less dense than solids. The forces between the particles are less effective, and the particles can move around each other. The particles in a liquid are arranged randomly.

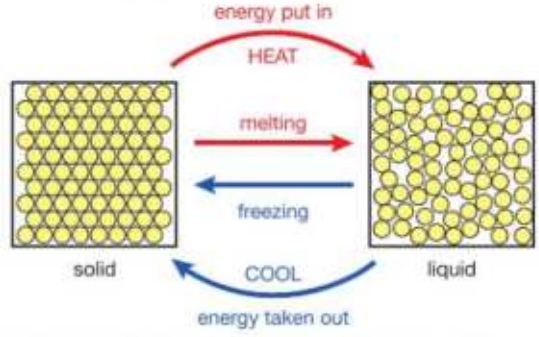
The particles in a gas are moving randomly at high speed in all directions. In a gas, the particles are much further apart and there are (almost) no forces of attraction between them.

The particles in a solid have less kinetic (movement) energy than the particles in a liquid, which have less **kinetic energy** than the particles in a gas.

INTERCONVERSIONS BETWEEN THE THREE STATES OF MATTER

CHANGING STATE BETWEEN SOLID AND LIQUID

If you heat a solid, the energy provided by the heat source makes the particles in the solid vibrate faster and faster. Eventually, they vibrate so fast that the forces of attraction between the particles are no longer strong enough to hold them together; the particles are then able to move around each other – the solid melts to form a liquid. The temperature at which the solid **melts** is called its **melting point**. The particles in the liquid have more kinetic energy than the particles in the solid so energy has to be supplied to convert a solid to a liquid.



▲ Figure 1.4 Melting to become a liquid – and freezing to become a solid.

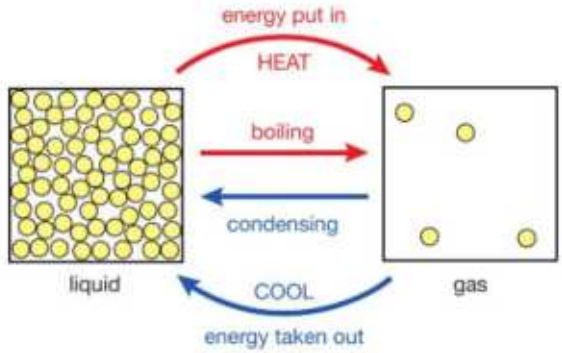
If the liquid is cooled again, the liquid particles will move around more and more slowly. Eventually, they are moving so slowly that the forces of attraction between them will hold them in a fixed position and the particles pack more closely together into a solid. The liquid freezes, forming a solid. The temperature at which this occurs is called the **freezing point**.

Although they are called different things depending which way you are going, the temperature of the melting point and that of the freezing point of a substance are exactly the same.

CHANGING STATE BETWEEN LIQUID AND GAS

There are two different ways this can happen, called **boiling** and **evaporation**.

BOILING



▲ Figure 1.5 Boiling to become a gas – and condensing to become a liquid.

Boiling occurs when a liquid is heated so strongly that the particles are moving fast enough to overcome all the forces of attraction between them. The stronger the forces of attraction between particles, the higher the boiling point of the liquid. This is because more energy is needed to overcome these forces of attraction.

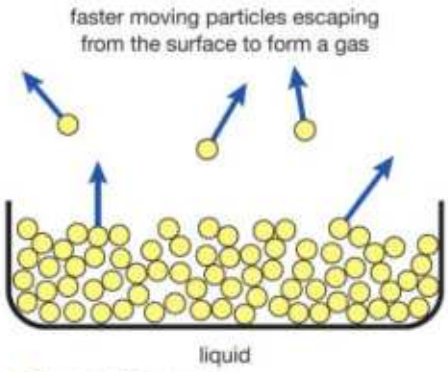
If a gas is cooled, the particles eventually move slowly enough that forces of attraction between them start to form and hold them together as a liquid. The gas condenses.

KEY POINT

Evaporation occurs at any temperature, but boiling only occurs at one temperature – the boiling point of the liquid. Puddles of water disappear quite quickly despite the outside temperature often being below 5 °C in the winter in the UK. The water in the puddles certainly does not boil at this temperature; the water evaporates. So water will evaporate at, for example, 5 °C but only boil at 100 °C.

EVAPORATION

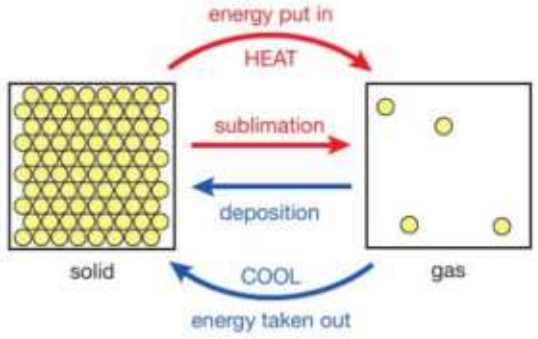
Evaporation is different. In any liquid or gas, the average speed of the particles varies with the temperature. But at each temperature, some particles will be moving faster than the average and others more slowly.



▲ Figure 1.6 Evaporation.

Some very fast particles at the surface of the liquid will have enough energy to overcome the forces of attraction between the particles – they will break away to form a gas. This is evaporation. You don't see any **bubbling**; the liquid just slowly disappears if it is open to the air. If the liquid is in a closed container, particles in the gas will also be colliding with particles at the surface of the liquid. If they are moving slowly enough they will be held by the attractive forces and become part of the liquid. In a closed container evaporation and **condensation** will both be occurring at the same time.

CHANGING STATE BETWEEN SOLID AND GAS: SUBLIMATION



▲ Figure 1.7 This change of state goes directly from a solid to a gas and from a gas to a solid.

A small number of substances can change directly from a solid to a gas, or from a gas to a solid, at normal **pressure** without involving any liquid in the process. The conversion of a solid into a gas is known as **sublimation** and the reverse process is usually called **deposition**.

KEY POINT

The process of a gas changing into a solid is given various names. Some people call it 'de-sublimation' or 'deposition' and others just use the word 'sublimation' again.



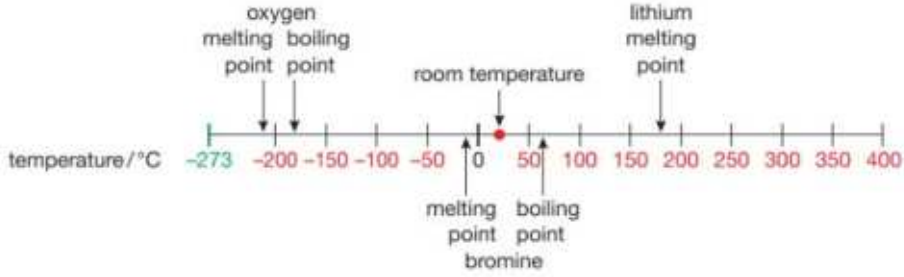
▲ Figure 1.8 Dry ice subliming. Notice the white solid carbon dioxide in the beaker. The white cloud is because the carbon dioxide gas produced is so cold that it causes water vapour in the air to condense. Carbon dioxide gas itself is invisible.

An example of a substance that sublimes is carbon dioxide. At ordinary pressures, there is no such thing as liquid carbon dioxide – it turns directly from a solid to a gas at –78.5 °C. Solid carbon dioxide is known as **dry ice**.

WORKING OUT THE PHYSICAL STATE OF A SUBSTANCE AT A PARTICULAR TEMPERATURE

A substance is a solid at temperatures below its melting point, between its melting point and its boiling point it is a liquid, and above its boiling point it is a gas.

In science we can decide whether a substance is a solid, a liquid or a gas at room temperature by looking at where its melting and boiling points are in relation to room temperature.



▲ Figure 1.9 A temperature line can be used to work out whether substances are solids, liquids or gases.

KEY POINT

Room temperature is different in different places but in science it is usually taken to mean a temperature between 20 and 25 °C. Because there is not just one fixed value, for changes of state that occur near room temperature we must be careful when making comparisons and make clear what value is being used as room temperature.

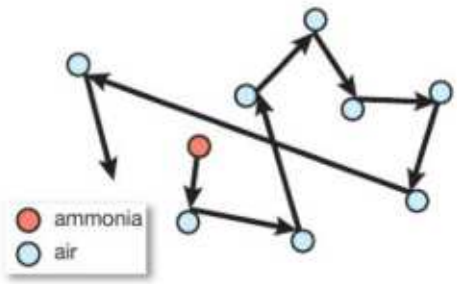
If we look at the temperature line in Figure 1.9 we can see that room temperature is above the boiling point of oxygen; this means that oxygen is a gas at room temperature.

Let's look at what happens when we heat bromine from –100 °C to 100 °C. As –100 °C is below bromine's melting point, bromine is a solid at –100 °C. As it is heated to –7 °C (its melting point) it becomes a liquid and it remains as a liquid until its temperature reaches the boiling point at 59 °C. Room temperature is between the melting point and the boiling point, which means that bromine is a liquid at room temperature. Above 59 °C bromine is a gas.

Lithium's melting point is above room temperature and so it is a solid at room temperature.

DIFFUSION

DIFFUSION IN GASES

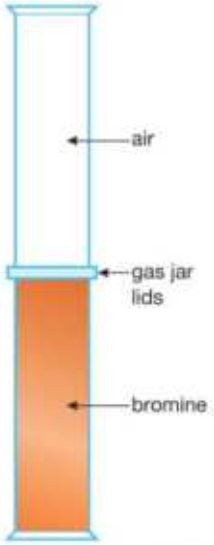


▲ Figure 1.10 An ammonia particle bouncing off air particles.

Suppose someone accidentally releases some smelly gas in the lab, ammonia for example. Within a minute or so, everybody in the lab will be able to smell it. That isn't surprising – particles in the gas are free to move around. What does need explaining, though, is why it takes so long.

At room temperature, ammonia particles travel at speeds of about 600 metres per second so they should be able to travel from one end of a lab to the other in less than 1/100 s (0.01 s). This would be the case if they travelled in a straight line without bumping into anything else. However, each particle is bouncing off air particles on its way. In the time that it takes for the smell to reach all corners of the lab, each ammonia particle may have travelled 30 or more kilometres!

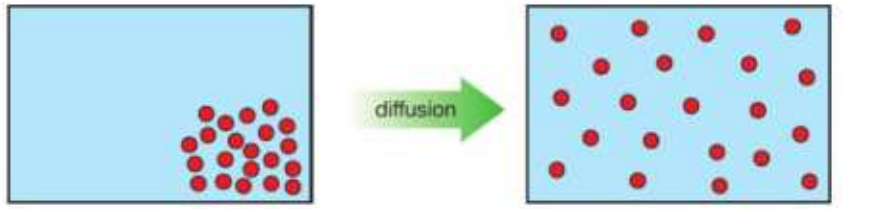
The spreading out of particles in a gas or liquid is known as **diffusion**. We say that ammonia particles *diffuse* through the air. A formal definition of diffusion is:



▲ Figure 1.12 Demonstrating diffusion in gases

Safety note: The teacher demonstration must be prepared in a working fume cupboard wearing eye protection and chemical-resistant gloves. Inhalation of bromine by anyone with breathing difficulties may produce a reaction, possibly delayed, requiring urgent medical attention.

Diffusion is the spreading out of particles from where they are at a high concentration (there are lots of them in a certain volume) to where they are at a low concentration (there are fewer of them in a certain volume).



▲ Figure 1.11 Diffusion involves the spreading out of particles.

You can show diffusion in gases very easily by using the apparatus in Figure 1.12. The lower gas jar contains bromine gas; the top one contains air. If the lids are removed, the brown colour of the bromine diffuses upwards until both gas jars are uniformly brown (the air particles also diffuse downwards). The bromine particles and air particles move around at random to give an even mixture – both gas jars contain air and bromine particles.

You can carry out the same experiment with hydrogen and air, but in this example you have to put a lighted splint in at the end to find out where the gases have gone. People often expect that the much less dense hydrogen will all go to the top gas jar. In fact, you will get identical explosions from both jars.

SHOWING THAT PARTICLES OF DIFFERENT GASES TRAVEL AT DIFFERENT SPEEDS

HINT

Don't worry if you don't know how to write symbol equations. This one is included here so that you can refer to it again in later revision.

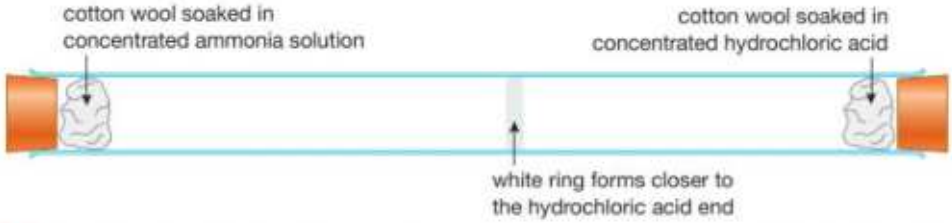
Safety note: The teacher demonstration requires eye protection and the avoidance of skin contact and inhalation of any fumes. The apparatus has to be cleaned up in a working fume cupboard.

KEY POINT

You will learn about relative molecular mass in Chapter 5. The relative molecular mass of ammonia is 17 and that of hydrogen chloride is 36.5.

This experiment relies on the reaction between ammonia (NH_3) and hydrogen chloride (HCl) gases to give white solid ammonium chloride (NH_4Cl):

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$



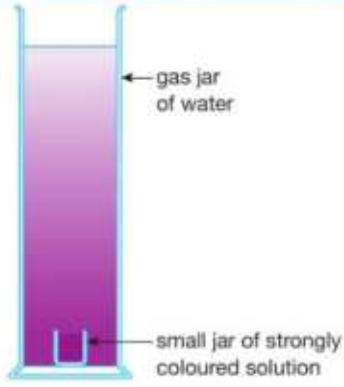
▲ Figure 1.13 Demonstrating that particles in ammonia and hydrogen chloride travel at different speeds.

Pieces of cotton wool are **soaked** in concentrated ammonia solution (as a source of ammonia gas) and concentrated hydrochloric acid (as a source of hydrogen chloride gas). These are placed in the ends of a long glass tube with rubber bungs to stop the poisonous gases escaping.

Ammonia particles and hydrogen chloride particles diffuse along the tube. A white ring of solid ammonium chloride forms where they meet. The white ring of ammonium chloride takes time to form (as it takes some time for the particles of ammonia and hydrogen chloride to diffuse along the tube), and appears *closer to the hydrochloric acid end*. Ammonia particles are lighter than hydrogen chloride particles and therefore move faster. The ammonia particles travel further in the same amount of time, which means that the ring forms further away from the ammonia end.

DIFFUSION IN LIQUIDS

Diffusion through a liquid is very slow if the liquid is completely still. For example, if a small jar of strongly coloured solution (such as potassium manganate(VII) solution) is placed in a gas jar of water, it can take days for the colour to diffuse throughout all the water. This is because *the particles in a liquid move more slowly than the particles in a gas*. The particles in a liquid are also much closer together than those in a gas and so there is less space for particles to move into without colliding with another one.



▲ Figure 1.14 Demonstrating diffusion in liquids

THE DILUTION OF COLOURED SOLUTIONS

Imagine you dissolve 0.01 g of potassium manganate(VII) in 1 cm^3 of water to make a deep purple solution. If we take the volume of 1 drop as 0.05 cm^3 we can work out that there are 20 drops in 1 cm^3 and each drop will contain 0.0005 g of potassium manganate(VII).

If you dilute this solution by adding water until the total volume is 10 000 cm^3, you should still just be able to see the purple colour.

There are now 200 000 drops in the solution. In order to see the colour each drop must contain at least one 'particle' of potassium manganate(VII), so there must be at least 200 000 'particles' in 0.01 g of potassium manganate(VII). This means that each 'particle' can't weigh more than 50 billionths of a gram (0.00000005 g).

This answer is not even close to the real answer. A potassium manganate(VII) 'particle' actually weighs about 0.000000000000000000000026 g and there are about 38 000 000 000 000 000 000 particles in 0.01 g! In reality, you need very large numbers of particles in each drop in order to see the colour.

REMINDER

Why the inverted commas around 'particle'? Potassium manganate(VII) is an *ionic compound* and contains more than one sort of particle. You will find out more about ionic compounds in Chapter 6.

THE SOLUBILITY OF SOLIDS

SOLUTES, SOLVENTS AND SOLUTIONS

When a solid dissolves in a liquid:

- the substance that dissolves is called the **solute**
- the liquid it dissolves in is called the **solvent**
- the liquid formed is a **solution**.

When you make a solution, the attractive forces between the particles in the solute (the solid) are being broken. At the same time, new attractive forces are being formed between the solvent particles and the solute particles. Whether a particular solid is soluble in any solvent depends on whether the new attractive forces are strong enough to overcome the old ones.

Only a certain amount of solute will dissolve in a fixed amount of solute at a particular temperature. When the maximum amount is dissolved a saturated solution is obtained.

A **saturated solution** is a solution which contains as much dissolved solid as possible at a particular temperature. There must be some undissolved solute present.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 What name is given to each of the following changes of state?

a Solid to liquid b Liquid to solid c Solid to gas d Gas to solid

SKILLS INTERPRETATION

2 a Draw diagrams to show the arrangement of the particles in a solid, a liquid and a gas.

b Describe the difference between the movement of particles in a solid and a liquid.

c The change of state from a liquid to a gas can be either evaporation or boiling. Explain the difference between evaporation and boiling.

SKILLS ANALYSIS

3 The questions refer to the substances in the table.

	Melting point / °C	Boiling point / °C
A	−259	−253
B	0	100
C	3700 (sublimes)	
D	−116	34.5
E	801	1413

a Write down the physical states of each compound at

i 30 °C.

ii −100 °C

iii 80 °C

SKILLS PROBLEM SOLVING

b Which substance has the greatest distance between its particles at 25 °C? Explain your answer.

SKILLS REASONING

c Why is no boiling point given for substance **C**?

d Which liquid substance would evaporate most quickly in the open air at 25 °C? Explain your answer.

4 Refer to Figure 1.13 on page 263 showing the diffusion experiment.

a Explain why the ring takes a few minutes to form.

b i If you heat a gas, what effect will this have on the movement of the particles?

ii In the light of your answer to i, what difference would you find if you did this experiment outside on a day when the temperature was 2 °C instead of in a warm lab at 25 °C? Explain your answer.

c Explain why the ring was formed nearer the hydrochloric acid end of the tube.

d Suppose you replaced the concentrated hydrochloric acid with concentrated hydrobromic acid. This releases the gas hydrogen bromide (HBr). Hydrogen bromide also reacts with ammonia to form a white ring.

i Suggest a name for the white ring in this case.

ii Hydrogen bromide particles are about twice as heavy as hydrogen chloride particles. What effects do you think this would have on the experiment?

2 ELEMENTS, COMPOUNDS AND MIXTURES

Most of the substances that we are familiar with from everyday life are mixtures. For example, the air that we breathe is a mixture containing elements such as nitrogen and oxygen, and compounds such as carbon dioxide and nitrogen oxides. The food that we eat and the drinks that we drink are mixtures. This chapter looks at the properties of elements, compounds and mixtures, and also how to separate the components of a mixture. Separation of mixtures is very important in the analysis of substances, such as in forensics.



▲ Figure 2.1 Gold is an element, but a gold ring made from 18-carat gold only contains 75% gold. The metal is a mixture of gold and, usually, copper.



▲ Figure 2.2 Pure water is a compound, but the water we drink is a mixture of water and other dissolved substances.

LEARNING OBJECTIVES

- Understand how to classify a substance as an element, compound or mixture
- Understand that a pure substance has a fixed melting and boiling point, but that a mixture may melt or boil over a range of temperatures
- Describe these experimental techniques for the separation of mixtures:
  - simple distillation
  - fractional distillation
  - filtration
  - crystallisation
  - paper chromatography
- Understand how a chromatogram provides information about the composition of a mixture
- Understand how to use the calculation of R_f values to identify the components of a mixture
- Practical: Investigate paper chromatography using inks/food colourings

REMINDER

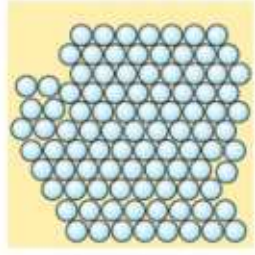
You might want to look at Chapter 3 if you do not already know the term 'atom'.

KEY POINT

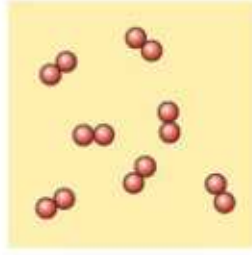
It isn't completely true to say that elements consist of only one type of atom. A better way of saying it would be that *all the atoms in an element have the same atomic number*. Most elements consist of mixtures of isotopes, which have the same atomic number, but different mass numbers (due to different numbers of neutrons). When we draw diagrams or make models, we aren't usually interested in the differences between the isotopes. Isotopes will be discussed in Chapter 3.

ELEMENTS

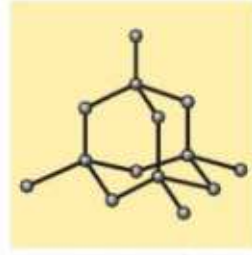
Elements are *substances that can't be split into anything simpler by* **chemical means**. An element contains only one type of atom (but see the key point in the margin). In models or diagrams they are shown as atoms of a single colour or size.



a pure metal such as magnesium



oxygen gas



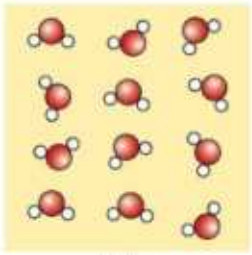
diamond (a form of carbon)

▲ Figure 2.3 Elements contain only one type of atom.

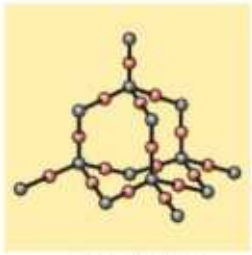
There are 118 elements and these are shown in the **Periodic Table**. Most of the elements occur naturally, such as hydrogen, helium and sulfur. Some others have to be made artificially, such as einsteinium.

COMPOUNDS

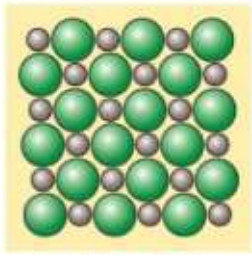
Compounds are formed when *two or more elements chemically combine*. The elements always combine in fixed proportions. For example, hydrogen and fluorine always combine to form hydrogen fluoride, with formula HF, whereas magnesium and fluorine always combine to form magnesium fluoride, with formula MgF_2 – the elements must combine in these ratios. Examples of other compounds are carbon dioxide (CO_2) and methane (CH_4). Diagrams of compounds show more than one type of atom bonded together.



water



silicon dioxide

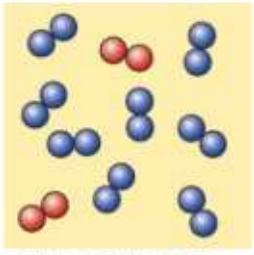


sodium chloride

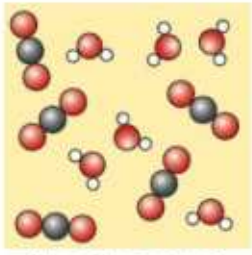
▲ Figure 2.4 Some compounds

MIXTURES

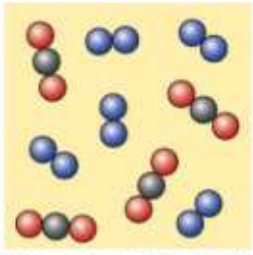
In a **mixture**, the various substances are mixed together and no chemical reaction occurs. Mixtures can be made from elements and/or compounds. The various components can be in any proportion, for example you can put any amount of sugar into your cup of tea or coffee (until it becomes saturated).



mixture of elements – nitrogen and oxygen



mixture of compounds – carbon dioxide and water (vapour)



mixture of an element with a compound – carbon dioxide and nitrogen

▲ Figure 2.5 Some mixtures

SIMPLE DIFFERENCES BETWEEN MIXTURES AND COMPOUNDS

PROPORTIONS

In water (a compound), every single water molecule has two hydrogen atoms combined with one oxygen atom. It never varies. In a mixture of hydrogen and oxygen gases, the two could be mixed together in any proportion.

If you had some iron metal and some sulfur, you could mix them in any proportion you wanted to. In iron sulfide (FeS), a compound, the proportion of iron to sulfur is always exactly the same.

PROPERTIES

In a mixture of elements, each element keeps its own properties, but the properties of the compound are quite different. For example, in a mixture of iron and sulfur, the iron is grey and the sulfur is yellow. The iron reacts with dilute acids such as hydrochloric acid to produce hydrogen; the sulfur doesn't react with the acid. However, the compound iron sulfide (FeS) reacts quite differently with acids to produce poisonous hydrogen sulfide gas, which smells of bad eggs.

A mixture of hydrogen and oxygen is a colourless gas which explodes when you put a flame to it. The compound, water, is a colourless liquid which just puts out a flame.

REMINDER

You can find out about the reactions of metals with dilute acids on pages 387–388. The reaction between iron sulfide and acids isn't needed for exam purposes at International GCSE.

EASE OF SEPARATION

Mixtures can be separated by **physical means**. Physical means are things like changing the temperature or dissolving part of the mixture in a solvent such as water; in other words, methods that don't involve any chemical reactions.

For example, a mixture of iron and sulfur is quite easy to separate into the two elements using a magnet. The iron sticks to the magnet and the sulfur doesn't. The elements in a compound cannot be separated by physical means. To convert iron sulfide into separate samples of iron and sulfur requires chemical reactions.

You can cool a mixture of hydrogen and oxygen gases to separate it by a physical process. Oxygen condenses into a liquid at a much higher temperature than hydrogen (–183 °C as opposed to –253 °C). This would leave you with liquid oxygen and hydrogen gas, which are easy to separate. But to separate water into hydrogen and oxygen, you have to change it chemically using **electrolysis**.

MELTING POINT AND BOILING POINT

Pure substances, such as elements and pure compounds, melt and boil at fixed temperatures. For example, the melting point of water is 0 °C and the boiling point 100 °C. However, mixtures usually melt or boil over a ***range*** *of temperatures*.

KEY POINT

A mixture is not a pure substance. If a sample contains only a small amount of an unwanted substance, the unwanted substance might be called an *impurity*.

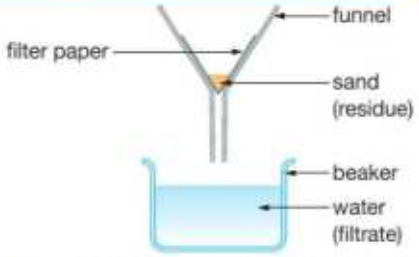
The presence of impurities lowers the melting point of a substance and raises the boiling point. For instance, dissolving 10 g of common (table) salt (sodium chloride) in 1 **litre** of water lowers the melting point to about –0.6 °C and raises the boiling point to about 100.2 °C.

The melting point can be very useful in determining whether or not a substance is pure. If you continue to study chemistry you might carry out a practical experiment to make some aspirin. In order to determine whether your sample is pure or not you can measure the melting point. You would record the temperature at which your sample starts to melt, and then you would record the temperature at which it has fully melted to completely form a liquid. Aspirin is a white powder that melts at 138 °C. If the melting point of the sample you made is 128–134 °C you can see that it is quite impure because it melts over a wide range of temperature (below the melting point of pure aspirin).

SEPARATION OF MIXTURES

Separating mixtures is extremely important in chemistry. For example, we can see this in the processing of crude oil, in producing fresh water from salt water and in the enrichment of uranium. In forensic science, the components of a mixture usually have to be separated before they can be analysed.

FILTRATION



▲ Figure 2.6 Filtration can be used to separate a mixture of sand and water.

Filtration can be used to separate a solid from a liquid.

For example, sand can be separated from water by filtration. The apparatus for filtration is shown in Figure 2.6.

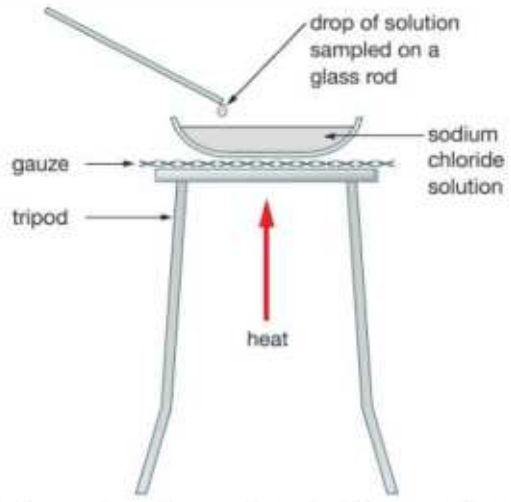
The substance left in the filter paper is called the **residue** and the liquid that comes through is called the **filtrate**.

Filtration can also be used to separate two solids from each other if only one of them is soluble in water (see below – rock salt).

CRYSTALLISATION

Crystallisation can be used to separate a solute from a solution. For example, it could be used to separate sodium chloride from a sodium chloride solution. The solution is heated in an evaporating basin to boil off some of the water until an almost saturated solution is formed. This can be tested by dipping a glass rod into the solution and seeing if crystals form quickly on its surface when it is removed. The Bunsen burner is then turned off and the crystals allowed to form as more water evaporates and the solution cools. The crystals can now be removed from the mixture by filtration.

The apparatus for crystallisation is shown in Figure 2.7.



▲ Figure 2.7 Crystallisation can be used to separate a solute from a solution.

MAKING PURE SALT FROM ROCK SALT



▲ Figure 2.8 Rock salt

We can use filtration and crystallisation to obtain pure salt from rock salt.

Rock salt consists of salt contaminated by various earthy or rocky impurities. These impurities aren't soluble in water.

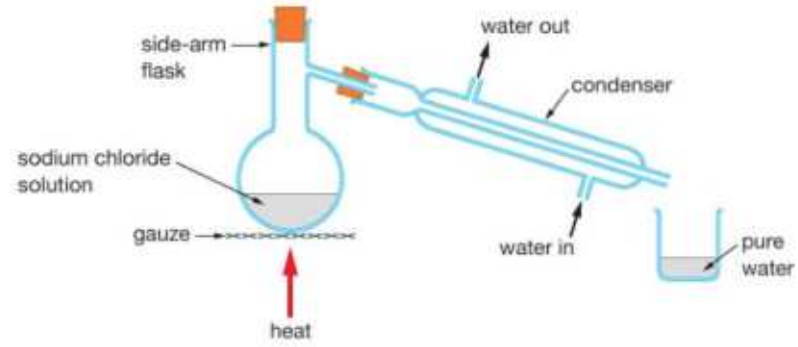
If you crush the rock salt and mix it with hot water, the salt dissolves, but the impurities don't. The impurities can be filtered off, and remain on the filter paper. The filtrate is then a salt solution. The solid salt can be obtained from the solution by crystallisation.

This is typical of the way you can separate any mixture of two solids, one of which is soluble in water and one of which isn't.

SIMPLE DISTILLATION

Simple distillation can be used to separate the components of a solution. Although we can use crystallisation to separate sodium chloride from a sodium chloride solution, we can also collect the water if we use simple distillation.

The water boils and is condensed back to a liquid by the condenser. The salt remains in the flask.



▲ Figure 2.9 Distilling pure water from sodium chloride solution.

KEY POINT

Notice that water is always fed into the condenser at the lower end. That way it fills the condenser jacket better and if the flow of water stops for any reason the condenser jacket remains full of water.

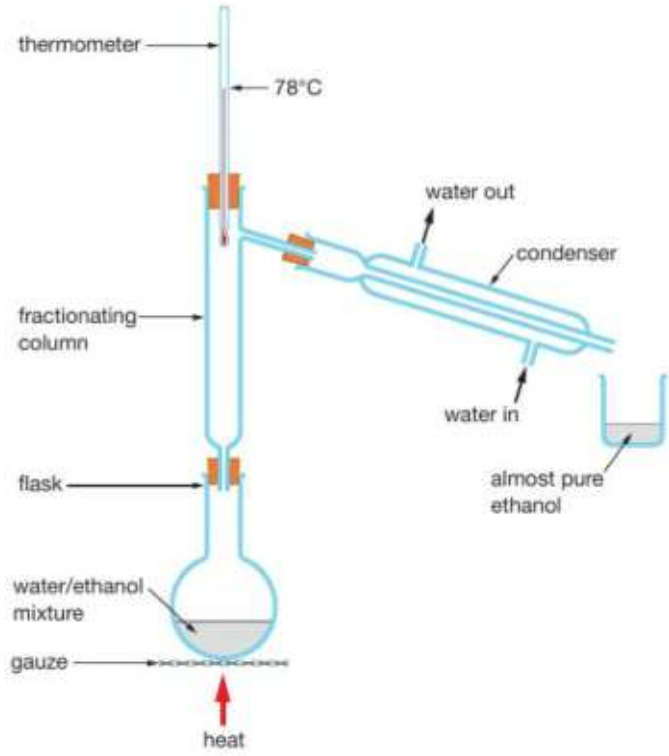
You could, of course, collect the salt from the solution as well as collecting pure water. The sodium chloride solution eventually becomes so concentrated that the salt will crystallise out.

FRACTIONAL DISTILLATION

Fractional distillation is used to separate a mixture of liquids such as ethanol (alcohol) and water. Ethanol and water are completely **miscible** with each other. That means you can mix them together in any proportion and they will form a single liquid layer. You can separate them by taking advantage of their different boiling points: water boils at 100 °C, ethanol at 78 °C.

EXTENSION WORK

The fractionating column is often packed with glass beads or something similar, although the separation of ethanol and water in the lab works perfectly well just with an empty column. For reasons that are beyond International GCSE, a high surface area in the column helps separation of the two vapours. The ethanol produced by this experiment is about 96% pure. For complicated reasons, again beyond International GCSE, it is impossible to remove the last 4% of water by distillation.



▲ Figure 2.10 Fractional distillation

Both liquids boil, but by careful heating you can control the temperature of the column so that all the water condenses in the column and **trickles** back into the flask. Only the ethanol remains as a vapour all the way to the top of the **fractionating column** and out into the condenser.

PAPER CHROMATOGRAPHY

Paper chromatography can be used to separate a variety of mixtures. However, at International GCSE level we will usually use it to separate mixtures of coloured inks or food colourings. Most inks and food colourings are not just made up of one colour but contain a mixture of dyes.

Paper chromatography can also be used to separate a mixture of colourless substances such as sugars, but then some method must be used to make the spots visible on the paper.

Safety note: Avoid skin contact with the solvents and dyes, especially if you have sensitive skin.

ACTIVITY 1

▼ PRACTICAL: INVESTIGATING THE COMPOSITION OF DYE WITH PAPER CHROMATOGRAPHY

We can investigate the composition of a mixture of coloured dyes using paper chromatography. To do this we carry out the following steps.

1. Draw a line with a pencil across a piece of chromatography paper; this line should be about 1 cm from the bottom of the paper. Do not use a pen as the colours in the ink may move up the chromatography paper with the solvent.
2. Put a spot (use a teat pipette or a capillary tube) of the mixture of dyes on the pencil line and allow it to dry.
3. Suspend the chromatography paper in a beaker that contains a small amount of solvent so that the bottom of the paper goes into the solvent. It is important that the solvent is below the pencil line so that the inks/colourings don't just dissolve in the solvent.
4. Put a lid (such as a watch glass) on the beaker so that the atmosphere becomes saturated with the solvent. This is to stop evaporation of the solvent from the surface of the paper.
5. When the solvent has moved up the paper to about 1 cm from the top, remove the paper from the beaker and draw a pencil line to show where the solvent got to. The highest level of the solvent on the paper at any time is called the *solvent front*.
6. Leave the paper to dry so that all the solvent evaporates.

For the solvent you can use water or a non-aqueous solvent (a solvent other than water). Which solvent you use depends on what substances are present in the mixture. A suitable solvent is usually found by experimenting with different ones.

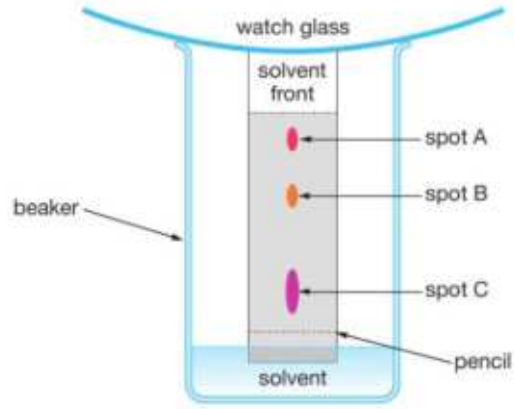
The dyes that make up the mixture will be different in two important ways:

- the affinity they have for the paper (how well they 'stick' to the paper)
- how soluble they are in the solvent which moves up the paper.

In Figure 2.11 spot C has hardly moved. Either it was not very soluble in the solvent or it has a very high affinity for the paper (or both). On the other hand, spot A has moved almost as far as the solvent. It must be very soluble in the solvent and not have much affinity for the paper. The pattern you get is called a **chromatogram**.

KEY POINT

If the dye does not move from the pencil line during an experiment, then the dye is not at all soluble in the solvent you are using. In this case, you need to find a different solvent. If the dye moves up the paper with the solvent front, the dye is too soluble in that solvent and, again, you have to try a different solvent.



◀ Figure 2.11 Paper chromatography

In this example, the mixture must have contained a minimum of three different dyes. We say a *minimum* of three dyes because there could be more – it is possible that one of the spots is made up of two coloured dyes that by concidence moved the same distance. You could only confirm this by doing the experiment again with a different solvent.

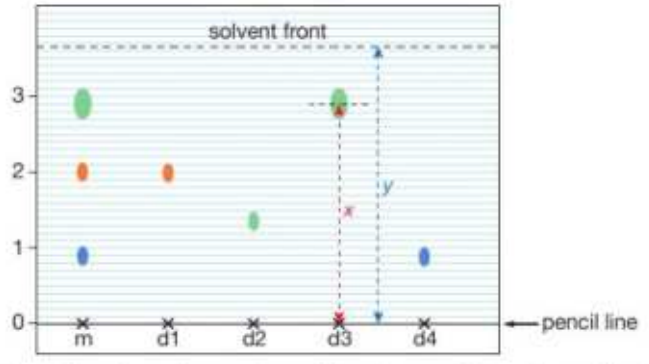


▲ Figure 2.12 A paper chromatography experiment

USING PAPER CHROMATOGRAPHY IN ANALYSIS

You can use paper chromatography to identify the particular dyes in a mixture. If you think that your mixture (m) could contain dyes d1, d2, d3 and d4, you can carry out an experiment to determine this.

A pencil line is drawn on a larger sheet of paper and pencil marks are drawn along the line to show the original positions of the various dyes placed on the line (see Figure 2.13). One spot is your unknown mixture; the others are single, known dyes. The chromatogram is then allowed to develop as before.



▲ Figure 2.13 Paper chromatography can be used to analyse a mixture. Lines will not be present on your paper, but they have been added here to help you measure the distances.

The mixture (m) has spots corresponding to dyes d1, d3 and d4. They have the same colour as spots in the mixture, and have travelled the same distance on the paper. Although dye d2 is the same colour as one of the spots in the mixture, it has travelled a different distance and so must be a different compound.

Instead of just saying the spots move different distances we can use the **R_f value** to describe how far the spots move. R_f stands for **retardation factor**. Each time we do a chromatography experiment the solvent (and therefore the spots) will move different distances along the paper. This means we can't just report the distance moved by a particular spot so we have to work out a ratio instead.

$$R_f = \frac{\text{distance moved by a spot (from the pencil line)}}{\text{distance moved by the solvent front (from the pencil line)}}$$

In Figure 2.13 $R_f = \frac{x}{y}$.

So in Figure 2.13 the R_f value for dye d3 is:

$$R_f = \frac{2.9}{3.6} = 0.81$$

HINT

Measure to the centre of the spot.

The R_f values of the dyes in mixture m are:

blue spot: $R_f = \frac{0.9}{3.6} = 0.25$

orange spot: $R_f = \frac{2.0}{3.6} = 0.56$

green spot: $R_f = \frac{2.9}{3.6} = 0.81$

The R_f values of dyes d1 to d4 are:

d1: $R_f = 0.56$

d2: $R_f = 0.36$

d3: $R_f = 0.81$

d4: $R_f = 0.25$

Because the spots in mixture m have the same R_f values as d1, d3 and d4, we can conclude that the mixture contains these dyes.

An R_f value must be between 0 and 1. If you get a number bigger than 1 you have probably divided the numbers the wrong way round. An R_f value has no units.

You have to be careful when using R_f values as they depend on the solvent used and on the type of paper. There was no problem in the experiment described above because the mixture and the individual dyes were all put on the same piece of paper. However, if the mixture was put on one piece of chromatography paper and the individual dyes on a separate piece, you can still compare R_f values as long as you use the same type of paper and the same solvent.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

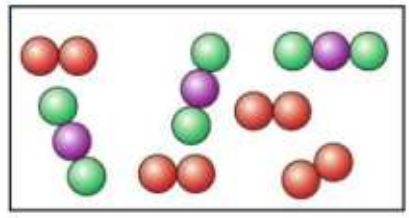
1 Classify each of the following substances as an element, compound or mixture:

sea water	hydrogen	honey
magnesium oxide	copper(II) sulfate	blood
calcium	mud	potassium iodide solution

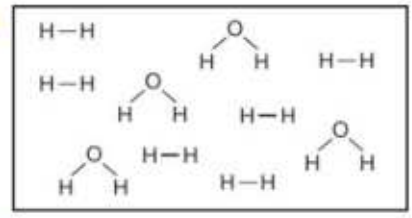
SKILLS ANALYSIS

2 Look at the diagrams below and classify each one as an element, compound or mixture.

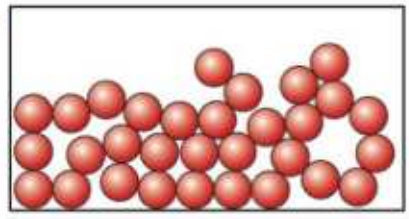
a



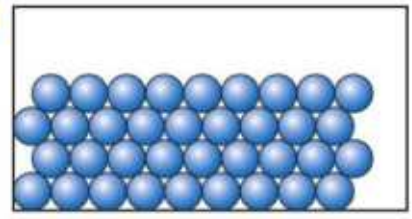
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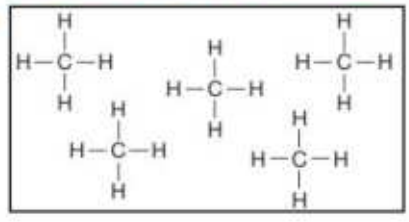
c



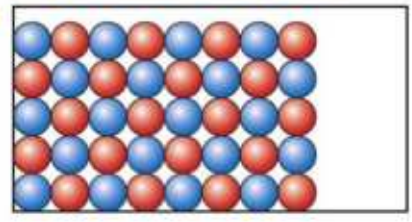
d



e



f



SKILLS REASONING, PROBLEM SOLVING

3 A teacher has found two white powders on a desk in the chemistry laboratory. She wants to test to see if they are pure substances, so she measures the melting points. Substance X melts at 122 °C and substance Y melts between 87 and 93 °C. Explain which one is the pure substance.

SKILLS DECISION MAKING

4 State which separation method you would use to carry out the following separations:

a Potassium iodide from a potassium iodide solution.

b Water from a potassium iodide solution.

c Ethanol from a mixture of ethanol and water.

d Red dye from a mixture of red and blue dyes.

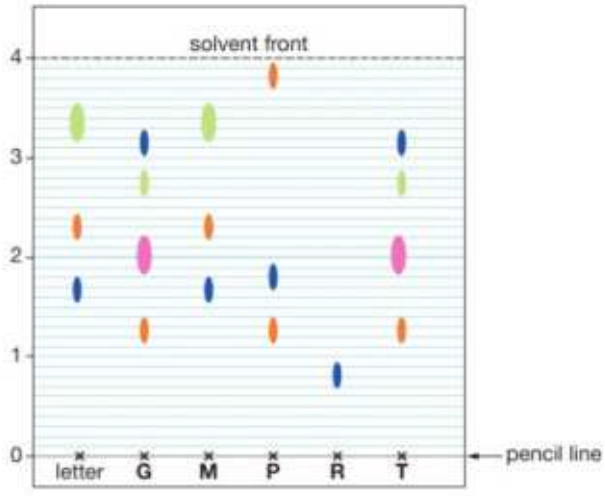
e Calcium carbonate (insoluble in water) from a mixture of calcium carbonate and water.

SKILLS CREATIVITY, DECISION MAKING

5 Suppose you had a valuable collection of small diamonds, which you kept safe from thieves by mixing them with white sugar crystals. You store the mixture in a jar labelled 'sugar'. Now you want to sell the diamonds. Describe how you would separate all the diamonds from the sugar.

SKILLS ANALYSIS

6 In order to identify the writer of an anonymous letter, a sample of ink from the letter was dissolved in a solvent and then placed on some chromatography paper. Spots of ink from the pens of five possible writers, **G**, **M**, **P**, **R** and **T**, were placed next to the sample on the chromatography paper. The final chromatogram looked like this:



a Which of the five writers is using ink that matches the sample from the letter?

b Which of the writers is using a pen that contains ink made from a single dye?

SKILLS PROBLEM SOLVING

c What is the R_f value of the blue dye in suspect **P**'s pen?

SKILLS ANALYSIS

d Which two of the five writers are using pens containing the same ink?

e Whose pen contained the dye that was most soluble in the solvent?

3 ATOMIC STRUCTURE

This chapter explores the nature of atoms and how they differ from element to element. The 118 elements are the building blocks from which everything is made, from a simple substance, such as carbon, to a more complex one, such as DNA.

LEARNING OBJECTIVES

- Know what is meant by the terms atom and molecule
- Know the structure of an atom in terms of the positions, relative masses and relative charges of sub-atomic particles
- Know what is meant by the terms atomic number, mass number, isotopes and relative atomic mass (A_r)
- Be able to calculate the relative atomic mass of an element (A_r) from isotopic abundances

Copper is an element. If you tried to cut it up into smaller and smaller pieces, the final result would be the smallest possible piece of copper. At that stage, you would have an individual copper atom. You can, of course, split that atom into smaller pieces (**protons**, **neutrons** and **electrons**), but you would no longer have copper. Therefore, an **atom** is the smallest piece of an element that can still be recognised as that element.



▲ Figure 3.1 New atoms are produced in stars . . .



▲ Figure 3.2 . . . or in nuclear processes such as nuclear bombs, nuclear reactors or radioactive decay.

ATOMS AND MOLECULES

Atoms can be joined together to make molecules. A **molecule** consists of two or more atoms chemically bonded (by covalent bonds). The atoms that make up a molecule can be from the same elements or different elements. A hydrogen (H_2) molecule (Figure 3.3a) consists of 2 hydrogen atoms chemically bonded together. A water (H_2O) molecule (Figure 3.3b) consists of 2 hydrogen atoms and an oxygen atom chemically bonded.



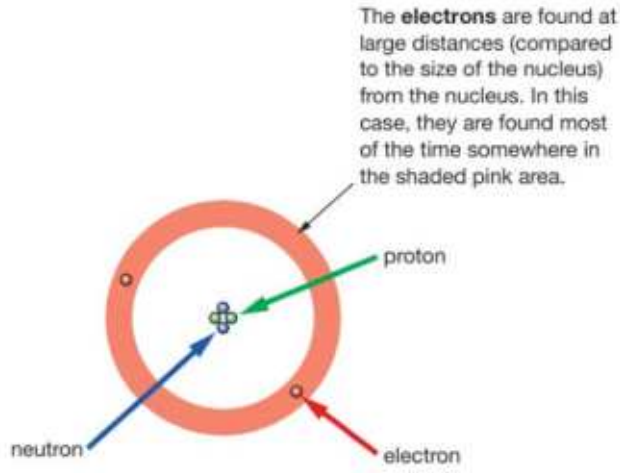
▲ Figure 3.3 (a) A H_2 molecule and (b) a H_2O molecule. The lines between the atoms represent chemical bonds.

KEY POINT

You may have come across diagrams of the atom in which the electrons are drawn orbiting the nucleus rather like planets around the sun. This can be misleading.
Electrons are constantly moving in the atom and it is impossible to know exactly where they are at any moment in time. You can only identify that they have a particular energy and that they are likely to be found in a certain region of space at some particular distance from the nucleus. Electrons with different energies are found at different distances from the nucleus.

THE STRUCTURE OF THE ATOM

Atoms are made of protons, neutrons and electrons. These particles are sometimes called *sub-atomic particles* because they are smaller than an atom.



▲ Figure 3.4 The structure of a helium atom

The **nucleus** of the atom contains protons and neutrons, and is shown highly magnified in Figure 3.4. In reality, if you **scale up** a helium atom to the size of a sports hall the nucleus would be no more than the size of a grain of sand.

The relative masses and charges of protons, neutrons and electrons are shown in Table 3.1.

Table 3.1 The properties of protons, neutrons and electrons

Particle	Relative mass	Relative charge
proton	1	+1
neutron	1	0
electron	1/1836	−1

HINT

$\frac{1}{1836}$ is approximately 0.0005.

Virtually all the mass of the atom is concentrated in the nucleus because electrons have a much smaller mass than protons and neutrons.

The masses and charges are measured relative to each other because the actual values are incredibly small. For example, it would take about 600 000 000 000 000 000 000 000 (6×10^{23}) protons to weigh 1 g.

KEY POINT

The atomic number defines an element and is unique to that element. We can identify an element by its atomic number instead of its name. We could talk about a wristwatch made from the element with atomic number 79 instead of talking about 'a gold wristwatch', or say that the element with atomic number 17 is poisonous instead of saying 'chlorine is poisonous'. However, these are more complicated ways of describing things!

ATOMIC NUMBER AND MASS NUMBER

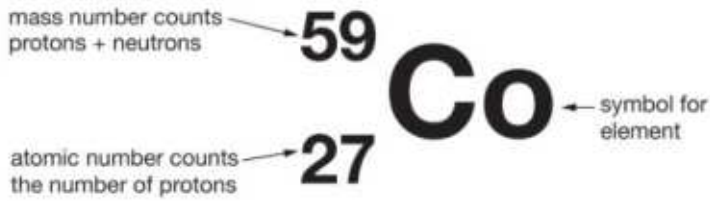
The number of protons in an atom's nucleus is called its **atomic number** or **proton number**. Each of the 118 different elements has a different number of protons. For example, if an atom has 8 protons it must be an oxygen atom:

atomic number = number of protons

The **mass number** (sometimes known as the **nucleon number**) counts the total number of protons and neutrons in the nucleus of the atom:

mass number = number of protons + number of neutrons

For any particular atom, this information can be shown as, for example:



This particular atom of cobalt contains 27 protons. To make the total number of protons and neutrons up to 59, there must also be 32 neutrons.

You can see from this that:

number of neutrons = mass number – atomic number

HINT

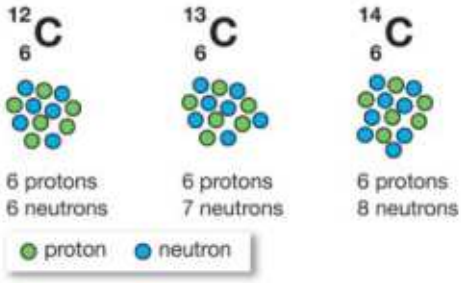
Be careful! When you are writing symbols with two letters, the first is a capital letter and the second must be lower case. If you write CO you are talking about carbon monoxide, not cobalt.

ISOTOPES

The number of neutrons in an atom can vary slightly. For example, there are three kinds of carbon atom called carbon-12, carbon-13 and carbon-14. They all have the same number of protons (because all carbon atoms have 6 protons, its atomic number), but the number of neutrons varies. These different atoms of carbon are called **isotopes**.

Isotopes are atoms (of the same element) which have the same atomic number but different mass numbers. They have the same number of protons but different numbers of neutrons.

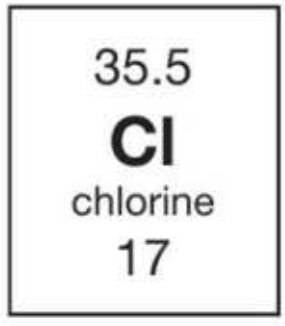
The fact that they have varying numbers of neutrons makes no difference to their chemical reactions. The chemical properties (how something reacts) are controlled by the number and arrangement of the electrons, and that is identical for all three isotopes.



▲ Figure 3.5 The nuclei of the three isotopes of carbon

RELATIVE ATOMIC MASS

You might have seen the following in a Periodic Table:



Chlorine appears to have a mass number of 35.5. If you calculate the number of neutrons for chlorine you obtain:

number of neutrons = 35.5 – 17 = 18.5

It is not possible to have half a neutron and so there must be something wrong with this. The number 35.5 is not actually the mass number for chlorine but rather the **relative atomic mass** (A_r). Chlorine consists of two isotopes, ^{35}Cl and ^{37}Cl, and a naturally occurring sample contains a mixture of these.

KEY POINT

The number above each symbol in the International GCSE Periodic Table papers is a relative atomic mass and not a mass number. However, in most cases the relative atomic mass stated is the same as the mass number of the most common isotope. The only exceptions to this are chlorine (35.5) and copper (63.5).

KEY POINT

This type of average is called a **weighted average** or weighted mean.

Relative atomic mass is the average mass of an atom, taking into account the amount of each isotope present in a naturally occurring sample of an element. It is explained in more detail in Chapter 5.

You can probably see that a naturally occurring sample of chlorine must contain more of the ^{35}Cl isotope than the ^{37}Cl isotope. This is because the relative atomic mass is closer to 35 than to 37.

We can calculate the relative atomic mass of an element by knowing how much of each isotope is present in a sample (the isotopic abundances) of that element, and then working out the average mass of an atom. This is done in exactly the same way as you would calculate a weighted average in maths. It can be understood more easily by looking at a worked example.

EXAMPLE 1

A naturally occurring sample of the element boron contains 20% ^{10}B and 80% ^{11}B. Calculate the relative atomic mass.

If we imagine there are 100 atoms we can work out that 20% of them, that is 20, will have mass 10 and 80 will have mass 11.

The total mass of the 20 atoms with mass 10 is 20×10.

The total mass of the 80 atoms with mass 11 is 80×11.

The total mass of all the atoms in the sample is $20 \times 10 + 80 \times 11$.

There are 100 atoms so we can work out the average by dividing the total mass by the total number of atoms (100):

$$\text{relative atomic mass} = \frac{20 \times 10 + 80 \times 11}{100} = 10.8$$

Therefore, the relative atomic mass of boron is 10.8.

Even if there are three or four different isotopes, you still do the calculation in the same way: calculate the total mass of 100 atoms, then divide the answer by 100.

THE ELECTRONS

COUNTING THE NUMBER OF ELECTRONS IN AN ATOM

Atoms are electrically neutral (they have no overall charge). The charge on a proton (+1) is equal but opposite to the charge on an electron (–1), and therefore in an atom:

number of electrons = number of protons

HINT

Remember that the number of protons is the same as the atomic number of the element.

So, if an oxygen atom (atomic number = 8) has 8 protons, it must also have 8 electrons; if a chlorine atom (atomic number = 17) has 17 protons, it must also have 17 electrons.

You will see that the key feature in this is knowing the atomic number. You can find the atomic number from the Periodic Table.

The number of protons in an atom is equal to the number of electrons. However, the atomic number is defined in terms of the number of protons because the number of electrons can change in chemical reactions, for example when atoms form **ions** (see Chapter 6).

THE PERIODIC TABLE

Chapter 4 deals in detail with what you need to know about the Periodic Table for International GCSE purposes.

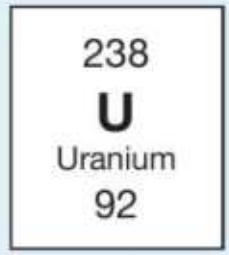
Atoms are arranged in the Periodic Table in order of increasing atomic number. You will find a full version of the Periodic Table in Appendix A on page 708. Most Periodic Tables have two numbers against each symbol; be careful to choose the right one. The atomic number will always be the smaller number. The other number will either be the mass number of the most common isotope of the element or the relative atomic mass of the element. The Periodic Table will clarify this.

You can use a Periodic Table to find out the number of protons, neutrons and electrons in an atom. Remember:

- the number of protons in an atom is equal to the atomic number
- the number of electrons in an atom is equal to the number of protons
- the number of neutrons in an atom = mass number – atomic number.

EXAMPLE 2

The symbol for uranium is given in a Periodic Table as:



Calculate the number of protons, neutrons and electrons in an atom of uranium.

The atomic number is the smaller number, so the atomic number of uranium is 92. The atomic number tells us the number of protons, therefore a uranium atom contains 92 protons.

The number of protons is equal to the number of electrons, therefore a uranium atom contains 92 electrons.

The number of neutrons = mass number – atomic number.

The number of neutrons = 238 – 92 = 146.

CHAPTER QUESTIONS

You will need to use the Periodic Table in Appendix A on page 708.

SKILLS CRITICAL THINKING

1 Atoms contain three types of particle: proton, neutron and electron.

a State where the protons and neutrons are in an atom.

b State which type of particle in the atom orbits the nucleus.

c State which one of the particles has a positive charge.

d State which two particles have approximately the same mass.

SKILLS CRITICAL THINKING

2 Fluorine atoms have a mass number of 19.

a Use the Periodic Table to find the atomic number of fluorine.

b Explain what *mass number* means.

c State the number of protons, neutrons and electrons in a fluorine atom.

SKILLS REASONING

d Explain why the number of protons in an atom must always equal the number of electrons.

SKILLS PROBLEM SOLVING

3 Work out the numbers of protons, neutrons and electrons in each of the following atoms:

a $^{56}_{26}Fe$ b $^{93}_{41}Nb$ c $^{235}_{92}U$

SKILLS CRITICAL THINKING

4 Chlorine has two isotopes, chlorine-35 and chlorine-37.

a Explain what *isotopes* are.

SKILLS PROBLEM SOLVING

b State the numbers of protons, neutrons and electrons in the two isotopes.

5 Lithium has two naturally occurring isotopes, ^{6}Li (abundance 7%) and ^{7}Li (abundance 93%). Calculate the relative atomic mass of lithium, giving your answer to 2 decimal places.

6 Magnesium has three naturally occurring stable isotopes, ^{24}Mg (abundance 78.99%), ^{25}Mg (abundance 10.00%) and ^{26}Mg (abundance 11.01%). Calculate the relative atomic mass of magnesium, giving your answer to 2 decimal places.

7 Lead has four naturally occurring stable isotopes. Calculate the relative atomic mass of lead given the data in the table.

Mass number	Natural abundance / %
204	1.4
206	24.1
207	22.1
208	52.4

8 Iridium has two naturally occurring isotopes, ^{191}Ir and ^{193}Ir.

a State the number of protons, neutrons and electrons in an ^{191}Ir atom.

SKILLS REASONING

b Explain the difference between the two isotopes.

c The relative atomic mass of iridium is 192.22. Explain whether a naturally occurring sample of iridium contains more ^{191}Ir or ^{193}Ir.

9 Use the Periodic Table to explain whether the following statement is true or false.

Considering only the most common isotope of each element, there is only one element that has more protons than neutrons.

4 THE PERIODIC TABLE



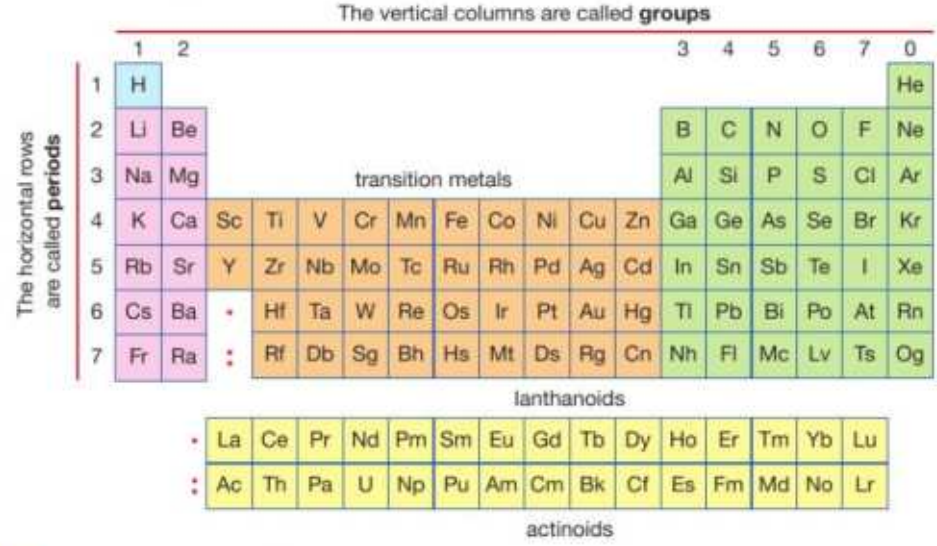
The Periodic Table shows all the elements in the universe and is one of the most important tools that a chemist has. The arrangement of the elements allows us to understand trends in properties and make predictions. The modern Periodic Table was first presented in 1869 by a famous Russian chemist, Dmitri Mendeleev (left). This chapter explores some of the features of the Periodic Table.

LEARNING OBJECTIVES

- Understand how elements are arranged in the Periodic Table:
  - in order of atomic number
  - in groups and periods
- Understand how to deduce the electronic configurations of the first 20 elements from their positions in the Periodic Table
- Understand how to use electrical conductivity and the acid–base character of oxides to classify elements as metals or non-metals
- Identify an element as a metal or a non-metal according to its position in the Periodic Table
- Understand how the electronic configuration of a main group element is related to its position in the Periodic Table
- Understand why elements in the same group of the Periodic Table have similar chemical properties
- Understand why the noble gases (Group 0) do not readily react

THE PERIODIC TABLE

The search for patterns in chemistry during the 19th century resulted in the modern Periodic Table. *The elements are arranged in order of atomic number* – the number of protons in the nuclei of the atoms.



▲ Figure 4.1 The Periodic Table

DID YOU KNOW?

You will sometimes see Group 0 labelled as Group 8. In more advanced Periodic Tables the groups are numbered from 1 to 18, including the transition metals.

REMINDER

For a larger version of the Periodic Table, including atomic numbers and other information, see Appendix A.

DID YOU KNOW?

Most International GCSE Periodic Tables stop at the end of the actinoid series, even though more elements continue to be discovered. Some tables completely omit the lanthanoids and actinoids because the emphasis in International GCSE is placed on a general understanding, which can easily be achieved with the main group and transition elements. Although sometimes called the rare earth metals, the lanthanoids are actually not that rare and are quite important in modern technology. Most of the actinoids are unstable and **undergo** radioactive decay.

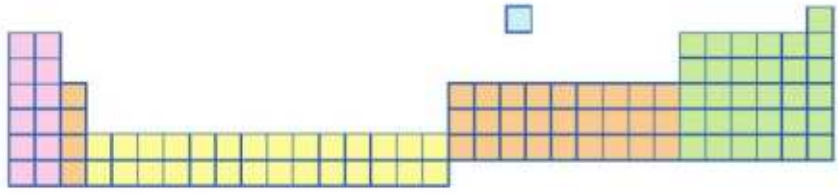
EXTENSION WORK

The third shell can actually hold up to 18 electrons. To explain why 2 electrons go into the fourth shell before the third shell is completely filled requires a more advanced understanding of electronic configurations. Each shell is actually made up of a series of subshells and some of these subshells overlap from one shell to another. The 4s subshell (which can hold 2 electrons) is lower in energy than the 3d subshell (which can hold 10 electrons) and so 2 electrons go into the fourth shell before the next 10 go into the third shell.

The vertical columns in the Periodic Table are called **groups**. The first seven groups are numbered from 1 to 7 and the final group is numbered 0. The elements in orange in Figure 4.1 are called the transition metals or transition elements. At this level, they are not usually included in the numbering of the groups. Some of the groups have names, e.g. Group 1 is the *alkali metals*, Group 7 is the ***halogens*** and Group 0 is the *noble gases*.

The horizontal rows in the Periodic Table are called **periods**. It is important to remember that hydrogen and helium make up Period 1.

The lanthanoids and actinoids are usually dropped out of their proper places and written separately at the bottom of the Periodic Table. There is a good reason for this. If you put them where they should be (as in Figure 4.2), everything has to be drawn slightly smaller to fit on the page. That makes it more difficult to read.



▲ Figure 4.2 The real shape of the Periodic Table

THE PERIODIC TABLE AND THE NUMBER OF PROTONS, NEUTRONS AND ELECTRONS

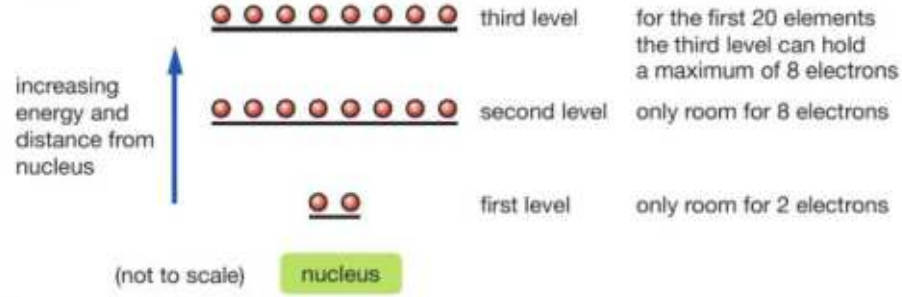
Most Periodic Tables have two numbers against each symbol. The atomic number will always be the smaller number. The other number will either be the mass number of the most common isotope of the element or the relative atomic mass of the element. The Periodic Table will tell you which.

You can use a Periodic Table to work out the number of protons, neutrons and electrons there are in atoms. Remember:

- the number of protons in an atom is equal to the atomic number
- the number of electrons in an atom is equal to the number of protons
- the number of neutrons in an atom = mass number – atomic number.

THE ARRANGEMENT OF THE ELECTRONS IN AN ATOM

The electrons move around the nucleus in a series of levels called **energy levels** or **shells**. Each energy level (shell) can only hold a certain number of electrons. Lower energy levels are always filled before higher ones. The lowest energy level is the closest one to the nucleus.



▲ Figure 4.3 The different energy levels for electrons in an atom showing the maximum number of electrons that each energy level (shell) can hold.

HOW TO WORK OUT THE ARRANGEMENT OF ELECTRONS IN AN ATOM

The arrangement of electrons in an atom is called its **electronic configuration**.

We will use chlorine as an example.

Look up the atomic number in the Periodic Table. (Make sure that you don't use the wrong number if you have a choice. The atomic number will always be the smaller one.)

The Periodic Table tells you that chlorine's atomic number is 17.

This tells you the number of protons. The number of electrons is equal to the number of protons.

There are 17 protons and so 17 electrons in a neutral chlorine atom.

Arrange the electrons in shells (energy levels), always completing an inner shell (lower energy level) before you go to an outer one. Remember that the first shell (lowest energy level) can take up to 2 electrons, the second one can take up to 8, and the third one also takes up to 8.

For chlorine the electrons will be arranged as follows: 2 in the first shell, 8 in the second shell and 7 in the third shell. This is written as 2, 8, 7. When you have finished, always check to make sure that the electrons add up to the right number, in this case 17.

DRAWING DIAGRAMS OF ELECTRONIC CONFIGURATIONS

When we draw a diagram of an atom we usually draw circles to represent the shells (energy levels); dots or crosses are then drawn on the circles to represent the electrons. You can choose to draw dots or crosses.

Hydrogen has 1 electron and helium has 2 in the first shell (lowest energy level).



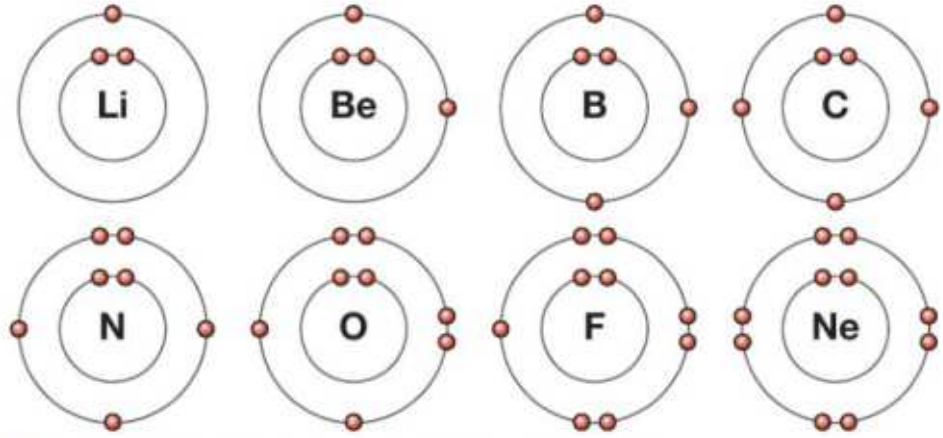
▲ Figure 4.4 Electronic arrangements of hydrogen and helium

KEY POINT

Drawing circles like this does not imply that the electrons are orbiting the nucleus along the circles.
The circles represent energy levels. The further away the level is from the nucleus, the higher its energy.
It is impossible to work out exactly how an electron is moving in that energy level.

The helium electrons are sometimes shown as a pair (as here), and sometimes as two separate electrons on opposite sides of the circle. Either form is acceptable.

The next 8 atoms are drawn like this:



▲ Figure 4.5 The electronic arrangements of the elements in Period 2

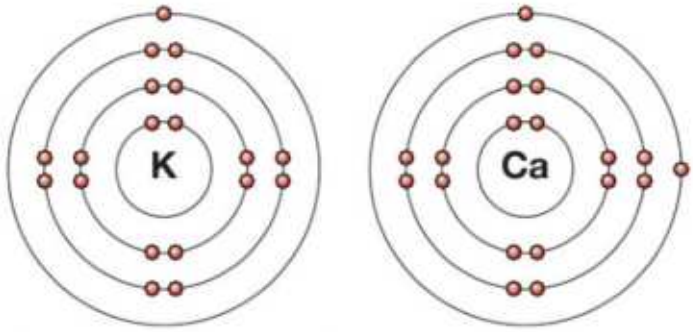
HINT

The terms 'shell' and 'energy level' are used quite interchangeably by chemists. To make things easier, we will just use one term, shell, from now on. If, however, you prefer the term energy level, that is absolutely fine and both terms will be accepted in the examination.

It does not matter at this level whether you draw the electrons singly or in pairs.

The atoms in the Periodic Table from sodium to argon fill the third shell in exactly the same way, and potassium and calcium start to fill the fourth shell.

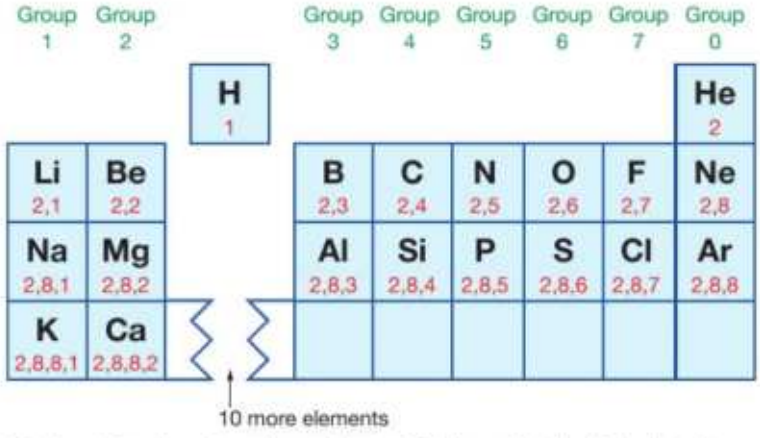
Potassium and calcium will look like this:



▲ Figure 4.6 Electronic arrangements of potassium and calcium

ELECTRONIC CONFIGURATIONS AND THE PERIODIC TABLE

The electronic configurations of the first 20 elements in the Periodic Table are shown in Figure 4.7.



▲ Figure 4.7 The electronic configurations of the first 20 elements in the Periodic Table

Two important facts:

- ***Elements in the same group in the Periodic Table have the same number of electrons in their outer shell.***
- ***The number of electrons in the outer shell is the same as the group number for Groups 1 to 7.***

So if you know that barium is in Group 2, you know it has 2 electrons in its outer shell, the same as all the other elements in Group 2. Iodine (Group 7) has 7 electrons in its outer shell. Lead (Group 4) has 4 electrons in its outer shell. Working out what is in their inner shells is much more difficult – the simple patterns we have described don't work beyond calcium.

The period number gives the number of occupied shells or the highest occupied shell.

So, calcium (electronic configuration = 2, 8, 8, 2) is in Period 4 and has four shells occupied; the outermost electron is in the fourth shell. Iodine is in Period 5 and has five occupied shells, and because it is also in Group 7 we can deduce that it has 7 electrons in the fifth shell.

ELEMENTS IN THE SAME GROUP IN THE PERIODIC TABLE HAVE SIMILAR CHEMICAL PROPERTIES

Groups in the Periodic Table contain elements with similar chemical properties – they react in the same way.

For example:

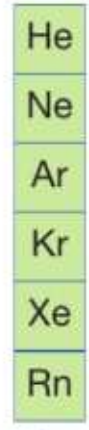
- all the elements in Group 1 react vigorously with water to form hydrogen and hydroxides with similar formulae: LiOH (lithium hydroxide), NaOH (sodium hydroxide), KOH (potassium hydroxide)
- all the elements in Group 7 react with hydrogen to form compounds with similar formulae: HF (hydrogen fluoride), HCl (hydrogen chloride), HBr (hydrogen bromide)
- all the elements in Group 2 form chlorides with similar formulae: $MgCl_2$, $CaCl_2$.

The reactions of atoms depend on how many electrons there are in their outer shell. These are the electrons which normally get involved when elements bond to other elements. Elements in the same group (apart from helium in Group 0) have the same number of electrons in their outer shell, therefore they react in similar ways.

THE NOBLE GASES

The Group 0 elements are known as the **noble gases** because they are almost completely unreactive, in fact the two at the top of the group, helium and neon, don't react with anything. The elements in Group 0 have 8 electrons in their outer shell (apart from helium, which has 2).

The lack of reactivity of the elements in Group 0 is associated with their electronic configurations. The noble gases are unreactive because *the outer shell is full, and so there is no tendency to lose, gain or share electrons in a chemical reaction*. You will learn more about how elements form compounds in Chapters 6 and 7.



▲ Figure 4.8 The noble gases

KEY POINT

The reason the noble gas group is usually called Group 0 and not Group 8 (which would seem more sensible because most of the elements have 8 electrons in their outer shell) is because when they were first discovered it was believed that noble gases did not combine with anything, they had zero combining power (valency). This is the only group where the group number does not tell you the number of electrons in the outer shell! The key point is that the noble gases (except helium) have 8 electrons in their outer shell. You will see in Chapters 6 and 7 that atoms tend to form compounds by losing/gaining or sharing electrons so that they have 8 electrons in their outer shell. The noble gases already have 8 electrons in their outer shell so they do not do that.

EXTENSION WORK

In reality, the outer shells of argon, krypton, xenon and radon are not full; in fact only helium and neon have full outer shells. The third shell can actually hold up to 18 electrons and the fourth up to 32 electrons.

METALS AND NON-METALS IN THE PERIODIC TABLE

The metals are on the left-hand side of the Periodic Table and the non-metals are on the right-hand side. Although the division into metals and non-metals is shown clearly in Figure 4.9, in practice there is a lot of uncertainty on the dividing line. For example, arsenic (As) has properties of both metals and non-metals.

KEY POINT

You may have noticed by now that hydrogen does not really fit into the Periodic Table properly. Although it has 1 electron in its outer shell, it is not in Group 1 because it does not have similar properties to the other elements in Group 1: it is not a metal and does not have similar chemical properties to the alkali metals.

EXTENSION WORK

If you are interested you could try an internet search for 'metallic hydrogen'.



▲ Figure 4.10 Copper, like all other metals, conducts electricity.

EXTENSION WORK

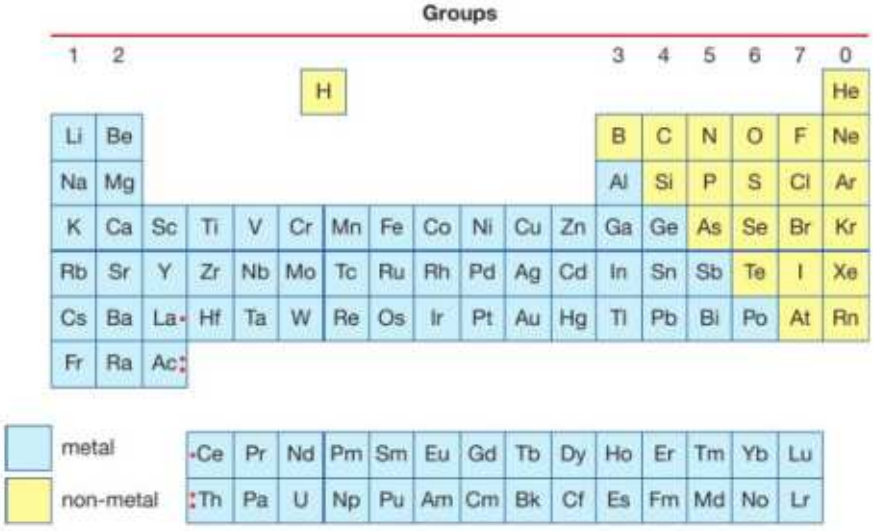
The reason that metals conduct electricity is due to the presence of delocalised electrons that are free to move.

KEY POINT

If a basic oxide is soluble in water it will dissolve to form an alkali. For example, sodium oxide reacts with water to form sodium hydroxide solution, an alkali. If an acidic oxide is soluble in water it will dissolve to form an acidic solution. For example, sulfur(IV) oxide reacts with water to form sulfurous acid.

KEY POINT

There are some exceptions to the rules. For example, some metals form **amphoteric** oxides (e.g. Al_2O_3), which react with acids and bases, and some non-metal oxides (e.g. CO) are neutral.



▲ Figure 4.9 Metals and non-metals

DIFFERENCES BETWEEN THE PROPERTIES OF METALS AND NON-METALS

There are many differences between the properties of metals and non-metals. Here, we will use two main ones to classify them: electrical conductivity and the acid–base character of their oxides.

Metals conduct electricity and non-metals do not generally conduct electricity. You may be familiar with the use of metals such as copper in electrical wires.

Non-metals do not conduct electricity (because there are no electrons that are free to move or mobile ions) but there are a few exceptions, such as graphite (a form of carbon) and silicon.

Metals generally form basic oxides. A basic oxide is one which reacts with acids to form salts. For example, copper forms copper(II) oxide (CuO). This reacts, for example, with sulfuric acid to form the salt copper(II) sulfate:

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

copper(II) oxide + sulfuric acid → copper(II) sulfate + water

The reactions between **bases** and acids will be discussed in more detail in Chapter 13.

Non-metals generally form acidic oxides. You may be familiar, for example, with sulfur(IV) oxide (SO_2) being one of the gases responsible for acid rain. Acidic oxides react with bases/alkalis to form salts. For example, carbon dioxide, an acidic oxide, reacts with sodium hydroxide, an alkali:

$$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$$

carbon dioxide + sodium hydroxide → sodium carbonate + water

Some other properties you might also associate with metals and non-metals are included in the list on the next page.



▲ Figure 4.11 Mercury has most of the properties of a metal (high density, shiny, conducts electricity, forms positive ions); the exception is that it is a liquid at room temperature.

Metals:

- tend to be solids with high melting and boiling points, and with relatively high densities (but as with several of the properties in this list, there are exceptions, for example mercury is a liquid)
- are shiny (have a metallic lustre) when they are polished or freshly cut
- are **malleable** (can be **hammered** into shape)
- are **ductile** (can be drawn into wires)
- are good conductors of electricity and heat
- form ionic compounds (see Chapter 6)
- form positive ions in their compounds (see Chapter 6).



▲ Figure 4.12 Sulfur crystals are shiny, but you wouldn't mistake them for a metal.

Non-metals:

- tend to have low melting and boiling points (there are some exceptions, e.g. carbon and silicon)
- tend to be brittle when they are solids
- don't have the same type of shine as metals
- don't usually conduct electricity; carbon (in the form of graphite) and silicon are again exceptions
- are poor conductors of heat (diamond is an exception; it is the best conductor of heat of all the elements)
- form both ionic and covalent compounds (see Chapters 6 and 7)
- tend to form negative ions in ionic compounds (see Chapter 6).

CHAPTER QUESTIONS

You will need to use the Periodic Table in Appendix A on page 708.

SKILLS CRITICAL THINKING

1 Answer the questions that follow using only the elements in this list:

caesium, chlorine, molybdenum, neon, nickel, nitrogen, strontium, tin.

a State the name of an element which is:
   i in Group 2
   ii in the same period as silicon
   iii in the same group as phosphorus
   iv in Period 6
   v a noble gas

b Divide the list of elements at the beginning of the question into two groups, metals and non-metals.

SKILLS INTERPRETATION

2 Draw diagrams to show the arrangement of the electrons in:

a sodium

b silicon

c sulfur

SKILLS CRITICAL THINKING

3 State the electronic configurations of the following atoms:

a fluorine

b aluminium

c calcium

SKILLS PROBLEM SOLVING

4 Find each of the following elements in the Periodic Table and state the number of electrons in its outer shell:

a arsenic, As

b bromine, Br

c tin, Sn

d xenon, Xe

SKILLS REASONING

5 The questions refer to the electronic configurations below. Don't worry if some of these are unfamiliar to you. All of these are the electronic configurations of neutral atoms.

A 2, 4

B 2, 8, 8

C 2, 8, 18, 18, 7

D 2, 8, 18, 18, 8

E 2, 8, 8, 2

F 2, 8, 18, 32, 18, 4

a Explain which of these atoms are in Group 4 of the Periodic Table.

b State which of these electronic configurations represents carbon.

c Explain which atoms are in Period 5 of the Periodic Table.

d Explain which of these electronic configurations represents an element in Group 7 of the Periodic Table.

e State which of these electronic configurations represent noble gases.

SKILLS PROBLEM SOLVING

f State the name of element **E** and explain how you arrived at your answer.

g State how many protons are present in an atom of element **F**. State the name of the element.

SKILLS INTERPRETATION

h Element **G** has one more electron than element **B**. Draw a diagram to show how the electrons are arranged in an atom of **G**.

SKILLS REASONING

6 Predict two properties of the element palladium, Pd (atomic number 46), or its compounds. The properties can be either physical or chemical.

7 Helium and neon do not form any compounds. Explain why the noble gases are unreactive.

8 The elements in the Periodic Table are arranged in order of atomic number. If they were arranged in order of mass number give the names of two elements that would be in different positions. Explain why this would cause a problem.

5 CHEMICAL FORMULAE, EQUATIONS AND CALCULATIONS

It is often important in chemistry to know how much of one substance reacts with a certain amount of another. To do this, we will learn about moles in this chapter.



▲ Figure 5.1 Each gold bar contains almost 4×10^{25} gold atoms. That's 4 followed by 25 noughts! Learning about the mole allows us to work out how many atoms are in something.

LEARNING OBJECTIVES

- Write word equations and balanced chemical equations (including state symbols):
  - for reactions studied in this course
  - for unfamiliar reactions where suitable information is provided
- Calculate relative formula masses (including relative molecular masses) (M_r) from relative atomic masses (A_r)
- Know that the mole (mol) is the unit for the amount of a substance
- Understand how to carry out calculations involving amount of substance, relative atomic mass (A_r) and relative formula mass (M_r)
- Calculate reacting masses using experimental data and chemical equations
- Calculate percentage yield
- Understand how the formulae of simple compounds can be obtained experimentally, including metal oxides, water and salts containing water of crystallisation
- Know what is meant by the terms empirical formula and molecular formula
- Calculate empirical and molecular formulae from experimental data
- Practical: Know how to determine the formula of a metal oxide by combustion (e.g. magnesium oxide) or by reduction (e.g. copper(II) oxide)

WRITING EQUATIONS

There are two types of chemical equation that you could be asked to write: **word equations** and symbol equations. Symbol equations are usually called *chemical equations* and you should only write a word equation if you are specifically asked to. All chemical equations must be balanced.

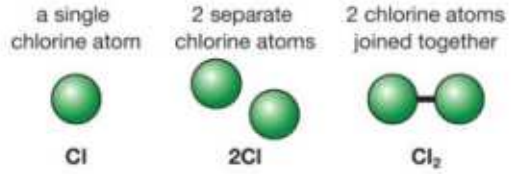
WHAT ALL THE NUMBERS MEAN

An example of a balanced chemical equation is:

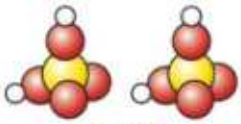
$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

When you write equations, it is important to be able to count how many of each type of atom you have. In particular, you must understand the difference between big numbers written in front of formulae (sometimes called **coefficients**), such as the **2** in **2**HCl, and the smaller, **subscript** (slightly lower on the line) numbers, such as the **3** in $CaCO_3$.

Another chemical equation is $2Cl \rightarrow Cl_2$. Here, **2Cl** represents 2 separate Cl atoms and **Cl_2** means that the atoms are joined together in a molecule.



▲ Figure 5.2 The difference between 2Cl and Cl_2



▲ Figure 5.3 $2H_2SO_4$. The sulfur atoms are shown in yellow, the oxygens in red and the hydrogens in white.

Another balanced chemical equation is $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$.

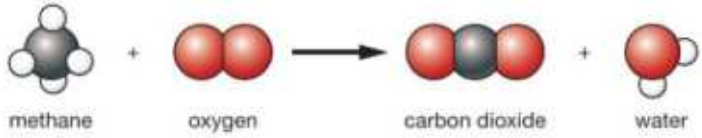
Look at the way the numbers work in $2H_2SO_4$. The big number in front tells you that you have 2 sulfuric acid (H_2SO_4) molecules. The subscript 4 tells you that you have 4 oxygen atoms in each molecule. A small, subscript number in a **formula** applies only to the atom immediately before it in the formula. If you count the atoms in $2H_2SO_4$ you will find 4 hydrogens, 2 sulfurs and 8 oxygens.

If you have brackets in a formula, the small number refers to everything inside the brackets. For example, in the formula $Ca(OH)_2$, the 2 applies to both the oxygen and the hydrogen. The formula shows 1 calcium, 2 oxygens and 2 hydrogens. You will learn more about how to work out the formulae of compounds in Chapter 6.

BALANCING EQUATIONS

Chemical reactions involve taking elements or compounds and moving their atoms around into new combinations. It follows that you must always end up with the same number of atoms that you started with.

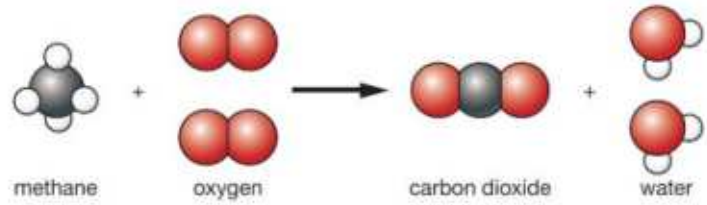
Imagine you had to write an equation for the reaction between methane, CH_4, and oxygen, O_2. Methane burns in oxygen to form carbon dioxide and water. Think of this in terms of rearranging the atoms in some models.



▲ Figure 5.4 Rearranging the atoms in methane and oxygen

If you count the atoms you had at the beginning (on the left-hand side of the arrow) and the atoms you have at the end (on the right-hand side of the arrow), you can see that this can't be right! During the rearrangement, we seem to have gained an oxygen atom and lost two hydrogens. The reaction must be more complicated than this. Since the substances are all correct, the proportions must be wrong.

Try again:



▲ Figure 5.5 A balanced equation for the reaction between methane and oxygen.

There are now the same number of each type of atom before and after. This is called **balancing the equation**.

In symbols, this equation would be:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Think of each symbol (C or H or O) as representing one atom of that element. Count them up in the equation, and check that there is the same number of atoms on both sides.

HOW TO BALANCE EQUATIONS

In order to balance equations you should adopt a systematic approach.

- Work across the equation from left to right, checking one element after another, except if an element appears in several places in the equation. In that case, leave the element until the end and you will often find that it has sorted itself out.
- If you have a group of atoms (like a sulfate group (SO_4), for example), which is unchanged from one side of the equation to the other, there is no reason why you can't just count that up as a whole group, rather than counting individual sulfurs and oxygens. It saves time.
- Check everything at the end to make sure you haven't changed something that you have already counted.

HINT

This is really important! You must never, never change a formula when balancing an equation. All you are allowed to do is to write big numbers in front of the formula.

EXAMPLE 1

Balance the equation for the reaction between zinc and hydrochloric acid:

$$Zn + HCl \rightarrow ZnCl_2 + H_2$$

Work from left to right. Count the zinc atoms: 1 on each side; no problem!

Count the hydrogen atoms: 1 on the left, 2 on the right. If you have 2 at the end, you must have started with 2. The only way of achieving this is to have 2HCl. (You must not change the formula to H_2Cl because this substance does not exist.)

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Now count the chlorines: there are 2 on each side. Good! Finally check everything again to make sure and you've finished.

	$Zn + 2HCl$		$\rightarrow$	$ZnCl_2 + H_2$	
numbers of atoms	Zn	1		Zn	1
	H	2		H	2
	Cl	2		Cl	2

EXAMPLE 2

Balance the equation for the **combustion** of ethane:

$$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$$

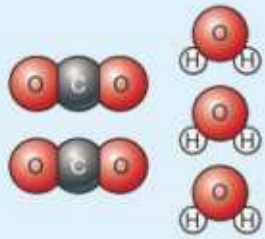
Starting from the left, balance the carbons:

$$C_2H_6 + O_2 \rightarrow 2CO_2 + H_2O$$

Now the hydrogens:

$$C_2H_6 + O_2 \rightarrow 2CO_2 + 3H_2O$$

Finally the oxygens: there are 7 oxygens ((2 × 2) + 3) on the right-hand side, but only 2 on the left. The problem is that the oxygens have to go around in pairs. So how can you obtain an odd number (7) of oxygens on the left-hand side?



▲ Figure 5.6 There are 7 O atoms in $2CO_2 + 3H_2O$

The trick with this is to allow yourself to have halves in your equation. 7 oxygen atoms, O, is the same as $3\frac{1}{2}$ oxygen molecules, O_2.

$$C_2H_6 + 3\tfrac{1}{2}O_2 \rightarrow 2CO_2 + 3H_2O$$

Now double everything to get rid of the half:

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

KEY POINT

In fact, it is acceptable to have halves in equations, but you don't usually come across them at Internaional GCSE.
You might reasonably argue that you can't have half an oxygen molecule, but to remove that problem all you have to do is double everything.

STATE SYMBOLS

HINT

Don't worry if this chemistry is new to you, or if at this stage you don't know what the state symbols should be. That is not important at the moment.

State symbols are often, but not always, written after the formulae of the various substances in an equation to show what physical state everything is in. You need to know four different state symbols:

(s) solid (l) liquid (g) gas (aq) in **aqueous** solution (dissolved in water)

So an equation might look like this:

$$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$$

This shows that *solid* potassium reacts with *liquid* water to make a *solution* of potassium hydroxide in water and hydrogen *gas*.

HINT

Remember that water is a liquid (l), not an aqueous solution (aq). An aqueous solution is formed when something is *dissolved in water*.

HOW MUCH OF EACH SUBSTANCE REACTS IN A CHEMICAL REACTION?

You can make iron(II) sulfide by heating a mixture of iron and sulfur:

$$Fe + S \rightarrow FeS$$

How do you know what proportions to mix them in? You can't just mix equal masses of them because iron and sulfur atoms don't weigh the same. Iron atoms contain more protons and neutrons than sulfur atoms, so an iron atom is one and three-quarter times heavier than a sulfur atom. In this or any other reaction, you can get the right proportions only if you know about the masses of the individual atoms that take part in the reaction.

RELATIVE ATOMIC MASS (A_r)

We have already looked at how to calculate relative atomic masses from the isotopic abundances in Chapter 3. Here we will look a little more closely at what exactly the relative atomic mass is.

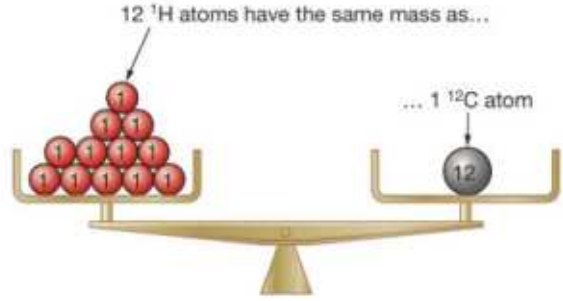
REMINDER

Remember that isotopes are atoms of the same element, but with different masses. Isotopes are explained in Chapter 3 (page 276).

EXTENSION WORK

This is a slight approximation. To be accurate, each of these hydrogen atoms has a mass of 1.008 on the carbon-12 scale. For International GCSE purposes, we take it as being exactly 1.

Atoms are amazingly small. The mass of a hydrogen atom is about 1.67×10^{-24} g (0.00000000000000000000000167 g). It is really difficult to use numbers such as this and so we use a scale of *relative* masses instead. The masses of atoms (and molecules) are compared with the mass of an atom of the carbon-12 isotope. We call this the carbon-12 scale. On this scale, one atom of the carbon-12 isotope weighs *exactly* 12 units and the mass of the most common hydrogen isotope is 1, which is a much simpler number to use!



▲ Figure 5.7 The most common hydrogen atom weighs one-twelfth as much as a ^{12}C atom.

The basic unit on the carbon-12 scale is $\frac{1}{12}$ of the mass of a ^{12}C atom, which is approximately the mass of the most common hydrogen atom. A fluorine-19 atom has a relative mass of 19 because its atoms have a mass 19 times that of $\frac{1}{12}$ of a ^{12}C atom. An atom of the most common isotope of magnesium weighs 24 times as much as $\frac{1}{12}$ of a ^{12}C atom, and is therefore said to have a relative mass of 24.

The masses we are talking about here are the masses of individual *isotopes*, but samples of an actual element contain different isotopes and so we need a measure of the average mass of an *atom* taking into account the different isotopes. This is the relative atomic mass.

The relative atomic mass of an element (as opposed to one of its isotopes) is given the symbol $\boldsymbol{A_r}$ and it is defined like this:

KEY POINT

Remember, to work out a weighted average we have to know how much of each isotope is present in a sample.

The relative atomic mass of an element is the weighted average mass of the isotopes of the element. It is measured on a scale on which a carbon-12 (^{12}C) atom has a mass of exactly 12.

Because we are talking here about *relative* masses they have no units.

On this scale, the relative atomic mass of chlorine is 35.45, that of lithium is 6.94 and that of sodium is 22.99 because we are taking into account the different isotopes, and are quoting an average mass for an atom. Although all elements consist of a mixture of isotopes, at International GCSE we only use relative atomic masses, including decimal places for Cl (35.5) and Cu (63.5), therefore we will take the relative atomic mass of lithium as 7 and that of sodium as 23.

HINT

Avoid the term 'relative molecular mass' because it can only properly be applied to substances which are actually molecules, that is, to covalent substances. You shouldn't use it for things like magnesium oxide or sodium chloride, which are ionic. Relative formula mass covers everything.

RELATIVE FORMULA MASS (M_r)

You can measure the masses of compounds on the same carbon-12 scale. For example, a water molecule, H_2O, has a mass of 18 on the carbon-12 scale. This means that a water molecule has 18 times the mass of $\frac{1}{12}$ of a ^{12}C atom.

If you are talking about compounds, you use the term **relative formula mass**. Relative formula mass is sometimes called relative molecular mass.

Relative formula mass is given the symbol $\boldsymbol{M_r}$.

CALCULATING SOME RELATIVE FORMULA MASSES

To find the relative formula mass (M_r) of magnesium carbonate, $MgCO_3$

Relative atomic masses: C = 12, O = 16, Mg = 24.

Add up the relative atomic masses to give the relative formula mass of the whole compound. In this case, you need to add up the masses of 1 × Mg, 1 × C and 3 × O.

$M_r = 24 + 12 + (3 \times 16)$
Mg C (3 × O)

$M_r = 84$

To find the relative formula mass of calcium hydroxide, $Ca(OH)_2$

Relative atomic masses: H = 1, O = 16, Ca = 40.

$M_r = 40 + (16 + 1) \times 2$
Ca O H

$M_r = 74$

To find the M_r of copper(II) sulfate crystals, $CuSO_4 \cdot 5H_2O$

This formula looks very different and a lot more complicated than the ones we have looked at above. When some substances crystallise from solution, water becomes chemically bound up with the salt. This is called **water of crystallisation**. The $5H_2O$ is water of crystallisation. The water is necessary to form crystals of copper(II) sulfate (and some other substances). There are always 5 water molecules associated with 1 $CuSO_4$ unit and they are part of the formula. Salts containing water of crystallisation are said to be **hydrated**. Other examples include $Na_2CO_3 \cdot 10H_2O$ and $MgCl_2 \cdot 6H_2O$.

Relative atomic masses: H = 1, O = 16, S = 32, Cu = 63.5.

It is easiest to work out the relative formula mass of water first:

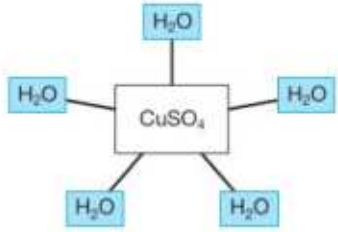
H_2O: $M_r = 2 \times 1 + 16 = 18$

Now add the correct number of waters on to the rest of the formula:

$CuSO_4 \cdot 5H_2O$: $M_r = 63.5 + 32 + (4 \times 16) + (5 \times 18) = 249.5$
Cu S (4 × O) (5 × H_2O)

HINT

Remember, you do not have to calculate the relative atomic masses, they will always be given to you in an exam, either in the question or on the Periodic Table. **If you use a Periodic Table, be sure to use the right number!** It will always be the larger of the two numbers given.



▲ Figure 5.8 A schematic diagram showing the formula of copper(II) sulfate crystals: there are five water molecules bonded to each copper(II) sulfate unit.

HINT

It is dangerous to calculate the number of hydrogens and oxygens separately. The common mistake is to work out 10 hydrogens (quite correctly!), but then only count 1 oxygen rather than 5.

USING RELATIVE FORMULA MASS TO FIND PERCENTAGE COMPOSITION

Having found the relative formula mass of a compound, we can work out the percentage by mass of any part of it. Examples make this clear.

To find the percentage by mass of copper in copper(II) oxide, CuO

Relative atomic masses: O = 16, Cu = 63.5.

M_r of CuO = 63.5 + 16 = 79.5

Of this, 63.5 is copper.

$$\text{Percentage of copper} = \frac{63.5}{79.5} \times 100$$

$$= 79.9\%$$

To find the percentage by mass of oxygen in sodium carbonate, Na_2CO_3

Relative atomic masses: Na = 23, C = 12, O = 16.

$M_r = (2 \times 23) + 12 + (3 \times 16)$

$= 106$

48 of this 106 is due to the oxygen (remember that there are 3 oxygens in the formula, so the total mass of oxygen is 3 × 16 = 48).

$$\text{Percentage of oxygen} = \frac{3 \times 16}{106} \times 100$$
$$= 45.3\%$$



▲ Figure 5.9 1-mole quantities (clockwise from upper left) of carbon (12 g), sulfur (32 g), iron (56 g), copper (63.5 g) and magnesium (24 g).

THE MOLE

In chemistry, the **mole** is a unit of the amount of substance. We can talk about an amount of substance in grams or an amount of substance in moles. The difference between expressing the amount of substance in moles or in grams is that 1 mole of any substance has its own particular mass. For example, 1 mole of water has a mass of 18 g, 1 mole of sulfur has a mass of 32 g and 1 mole of magnesium oxide has a mass of 40 g. The abbreviation for mole is **mol**.

We can therefore talk, for example, about an amount of water as 36 g or 2 mol, since 1 mol of water has a mass of 18 g. 36 g of sulfur, however, would only be 1.125 mol and 36 g of magnesium would be 1.5 mol because the mass of 1 mol of sulfur is 32 g and that of 1 mol of magnesium is 24 g.

Some people talk about the *amount in moles* and others talk about the *number of moles*. This is like talking about the *mass of a substance* or the *number of grams*. For example, we could say that the amount in grams of water is 36 g or the number of grams of water is 36 g. Similarly, we can say that the amount in moles of water is 2 mol or the number of moles of water is 2 mol.

CALCULATING THE MASSES OF A MOLE OF SUBSTANCE

You find the mass of 1 mole of a substance by calculating the relative formula mass (M_r) and attaching the units, grams.

1 mole of oxygen gas, O_2

Relative atomic mass: O = 16.

$$M_r \text{ of } O_2 = 2 \times 16$$
$$= 32$$

1 mole of oxygen, O_2, has a mass of 32 g.

1 mole of calcium chloride, $CaCl_2$

Relative atomic masses: Cl = 35.5, Ca = 40.

$$M_r \text{ of } CaCl_2 = 40 + (2 \times 35.5)$$
$$= 111$$

1 mole of calcium chloride has a mass of 111 g.

1 mole of iron(II) sulfate crystals, $FeSO_4 \cdot 7H_2O$

Relative atomic masses: H = 1, O = 16, S = 32, Fe = 56.

$$M_r \text{ of crystals} = 56 + 32 + (4 \times 16) + \{7 \times [(2 \times 1) + 16]\}$$

1 mole of iron(II) sulfate crystals has a mass of 278 g.

THE IMPORTANCE OF QUOTING THE FORMULA

Whenever you talk about a mole of something, you *must* quote its formula, otherwise there is a risk of confusion.

For example, if you talk about 1 mole of oxygen, this could mean:

1 mole of oxygen atoms, O, with a mass of 16 g

1 mole of oxygen molecules, O_2, with a mass of 32 g.

HINT

We often use the term '**molar mass**' instead of 'mass of 1 mole'.

EXTENSION WORK

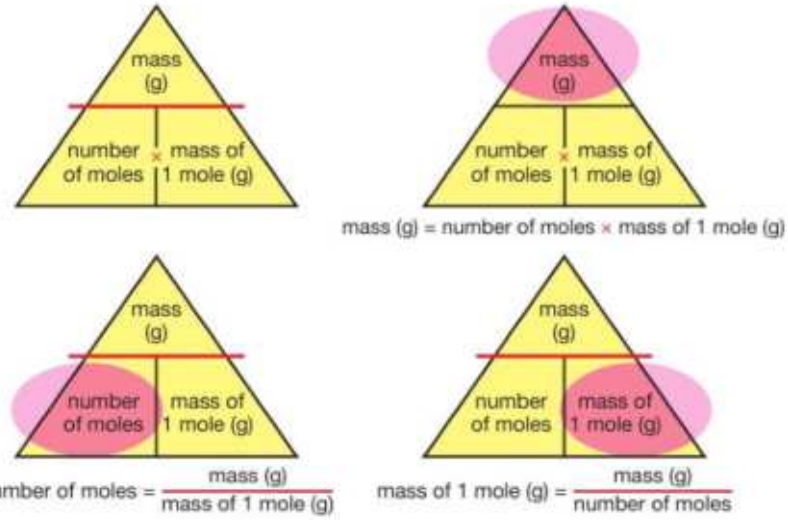
To be 100% correct 'molar mass' and 'mass of 1 mole' are not exactly the same thing and have different units: molar mass has units of g/mol and the mass of 1 mole has units of g. You are unlikely to come across the distinction between these at International GCSE.

SIMPLE CALCULATIONS WITH MOLES

You need to be able to interconvert between a mass in grams and an amount in moles for a given substance. There is a simple formula that you can learn:

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{mass of 1 mole (g)}}$$

You can rearrange this formula to find whatever you want. If rearranging this expression causes you problems, you can learn a simple triangular arrangement to help you.



▲ Figure 5.10 Converting between mass in grams and number of moles.

Look at this carefully and make sure that you understand how you can use it to deduce the three equations that you might need.

Finding the mass of 0.2 mol of calcium carbonate, $CaCO_3$

Relative atomic masses: C = 12, O = 16, Ca = 40.

First find the relative formula mass of calcium carbonate.

$$M_r \text{ of } CaCO_3 = 40 + 12 + (3 \times 16)$$
$$= 100$$

1 mol of $CaCO_3$ has a mass of 100 g.

HINT

Don't get too reliant on learning formulae for doing simple calculations. If 1 mole weighs 100 g, it should be fairly obvious to you that 2 moles will weigh twice as much, 10 moles will weigh 10 times as much and 0.2 moles will weigh 0.2 times as much.

$$\text{Mass (g)} = \text{number of moles} \times \text{mass of 1 mole (g)}$$
$$= 0.2 \times 100$$
$$= 20\,\text{g}$$

0.2 mol of $CaCO_3$ has a mass of 20 g.

Finding the number of moles in 54 g of water, H_2O

Relative atomic masses: H = 1, O = 16.

1 mol of H_2O has a mass of 18 g.

HINT

If 1 mol weighs 18 g, then you need to find out how many times 18 goes into 54 to find out how many moles you have. On the other hand, if you feel safer using a formula, use it.

$$\text{Number of moles} = \frac{\text{mass (g)}}{\text{mass of 1 mole (g)}}$$
$$= \frac{54}{18}$$
$$= 3\,\text{mol}$$

54 g of water is 3 mol.

EXTENSION WORK

Moles and the Avogadro constant

Imagine you had 1 mole of ^{12}C. It would have a mass of 12 g and contain a very large number of carbon atoms, in fact about 6×10^{23} carbon atoms, which is 6 followed by 23 noughts. This number of atoms in 12 g of ^{12}C is called the **Avogadro constant**.

1 mole of anything else contains this same number of particles. For example:

1 mole of magnesium contains 6×10^{23} magnesium atoms, Mg, and has a mass of 24 g.

1 mole of water contains 6×10^{23} water molecules, H_2O, and has a mass of 18 g.

This is the reason that we use moles: if we know the number of moles we also know how many particles are present. If we know how many particles are present, we can work out how much of one substance reacts with a certain amount of another.



▲ Figure 5.11 Approximately 1×10^{32} water molecules go over Niagara Falls every second during the summer. That's 100 million million million million million water molecules per second.

FORMULAE

The formula of sulfur dioxide is SO_2. We can see that there are 2 O atoms for each S atom. If we had 1 mol SO_2 we would still have twice as many O atoms as S atoms; there would be 1 mol S atoms and 2 mol O atoms. If we know that in a certain sample of sulfur dioxide we have 0.1 mol of S atoms we also know that we must have 0.2 mol O atoms. 0.2 mol contains twice as many atoms as 0.1 mol.

If we did an experiment and found that a compound contained 0.2 mol Ca and 0.2 mol O, then we could work out that the formula must be CaO because there are the same number of Ca atoms as O atoms.

If a compound contains 0.4 mol Mn and 0.8 mol O then the formula must be MnO_2 because there are twice as many O atoms as Mn atoms.

The formulae that we have found here are called *empirical formulae*.

The empirical formula shows the simplest whole number ratio of the atoms present in a compound.

There is another type of formula that we will come across, called the *molecular formula*.

The molecular formula shows the actual number of atoms of each element present in a molecule (covalent compound) or formula unit (ionic compound) of a compound.

The molecular formula can be the same as the empirical formula or a multiple of the empirical formula. The empirical formula of calcium oxide is CaO and the molecular formula is also CaO. The empirical formula of hydrogen peroxide is HO and the molecular formula is H_2O_2.

In order to work out the molecular formula from the empirical formula we need more information – the M_r of the compound. We will look at this again below.

WORKING OUT EMPIRICAL FORMULAE

In order to find out the empirical formula of a compound such as copper oxide, we need to know how many atoms of copper combine with how many atoms of oxygen. We can work out the number of atoms from the number of moles. If we know the ratio between the number of copper atoms and oxygen atoms in the compound we know the formula.

KEY POINT

0.02 mol of atoms is twice as many atoms as 0.01 mol of atoms.

HINT

More significant figures should have been used for the number of moles in the examples on this page but these have been omitted for simplicity.

EXAMPLE 3

A sample of a compound contains 1.27 g of Cu and 0.16 g of O. Calculate the empirical formula. (A_r of Cu = 63.5, A_r of O = 16)

It is easiest to do this in columns using a table:

	Cu	O
masses / g	1.27	0.16
find the number of moles of atoms by dividing the mass by the mass of 1 mole of atoms	1.27/63.5	0.16/16
number of moles of atoms	0.02	0.01
divide by the smaller number to find the ratio	0.02/0.01	0.01/0.01
ratio of moles	2	1
empirical formula	Cu_2O	

From calculating the number of moles of Cu and O we can see that there are twice as many moles of Cu and therefore there must be twice as many Cu atoms as O atoms in the compound.

It is important to remember in this calculation that we are working out how many *atoms* of copper combine with how many *atoms* of oxygen so we divide the mass of oxygen by 16 (the mass of 1 mole of oxygen atoms) rather than by 32 (the mass of 1 mole of oxygen molecules).

EXAMPLE 4

A sample of a compound contains 0.78 g of K, 1.10 g of Mn and 1.28 g of O. (A_r of K = 39, A_r of Mn = 55, A_r of O = 16)

Again, we use a table:

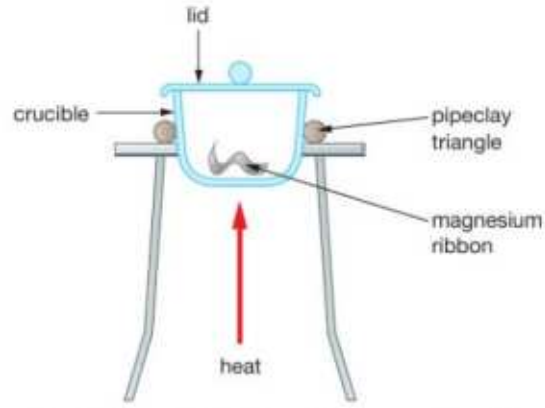
	K	Mn	O
masses / g	0.78	1.10	1.28
find the number of moles of atoms by dividing the mass by the mass of 1 mole of atoms	0.78/39	1.10/55	1.28/16
number of moles of atoms	0.02	0.02	0.08
divide by the smallest number to find the ratio	0.02/0.02	0.02/0.02	0.08/0.02
ratio of moles	1	1	4
empirical formula	$KMnO_4$		

The empirical formula of this compound is $KMnO_4$.

Safety note: Wear eye protection and take care not to get burned when raising the crucible lid with tongs. The crucible will stay very hot for some time.

ACTIVITY 2

▼ PRACTICAL: INVESTIGATING THE FORMULA OF A METAL OXIDE BY COMBUSTION



▲ Figure 5.12 Apparatus for determining the formula of magnesium oxide

KEY POINT

How do we know when the reaction has finished? We can generally see when there is no more reaction because nothing is happening in the crucible. We can also check by weighing the crucible and contents, then heating it and weighing again. If the mass is higher when we weigh it again then this indicates that a reaction has occurred. We keep heating and weighing until the mass stays constant.

We can find the formula of magnesium oxide by burning magnesium in oxygen and looking at how the mass changes. The following procedure is usually used:

- Weigh a crucible with a lid.
- Place a piece of magnesium ribbon about 10 cm long in the crucible and weigh the crucible and contents.
- Set up the apparatus as shown in Figure 5.12.
- Heat the crucible strongly (a roaring flame).
- Lift the lid every few seconds.
- When the reaction is finished, allow the crucible and contents to cool.
- Weigh the crucible and contents.

When the magnesium burns it does so with a bright white flame. Magnesium oxide, a white powder, is produced in the reaction.

A lid is placed on the crucible to prevent the white powder (magnesium oxide) escaping but the lid must be lifted every few seconds to allow oxygen into the crucible to react with the magnesium.

A set of results for this practical could be:

mass of empty crucible / g	32.46
mass of crucible + magnesium / g	32.70
mass of crucible + contents at end of experiment / g	32.86

We can work out the mass of magnesium by subtracting the mass of the crucible from the mass of the crucible + magnesium:

$$\text{mass of magnesium} = 32.70 - 32.46 = 0.24\,\text{g}$$

The reason that the mass increases is because the magnesium combines with the oxygen in the air. The mass of magnesium oxide is greater than the mass of just magnesium due to the extra oxygen.

KEY POINT

Remember: Number of moles is mass in grams divided by the mass of 1 mole in grams.

The overall reaction that occurred was:

$$2Mg + O_2 \rightarrow 2MgO$$

magnesium + oxygen → magnesium oxide

The type of reaction that occurred was combustion.

When we do this experiment in practice, it is not very often that the ratio comes out as 1:1. There are things that may go wrong with this experiment which could affect the results, such as:

- some of the magnesium oxide powder might escape when the lid is lifted
- not all the magnesium might have reacted
- the magnesium can also react with nitrogen in the air.

HINT

The original masses were measured to 2 significant figures so the number of moles should also be given to 2 significant figures (0.010). If you write 0.01 for the number of moles of atoms in the exam, this will be fine and still give you the correct answer.

Safety note: The teacher demonstrating needs to wear a face shield and use safety screens. The pupils require eye protection and should be no closer than 2 metres. If a drying agent is needed anhydrous calcium chloride should be used NOT concentrated sulfuric acid.

KEY POINT

We must always make sure that the tube is filled with hydrogen before lighting the stream of hydrogen because a mixture of hydrogen and oxygen is explosive! It is therefore important to let the stream of hydrogen gas flow through the tube for a little while (to **flush out** all the oxygen) before lighting it or lighting the Bunsen burner.

We can work out the mass of oxygen that combines with the magnesium:

mass of oxygen = 32.86 – 32.70 = 0.16 g

In order to find the formula of magnesium oxide we need to work out how many moles of magnesium atoms combine with how many moles of oxygen atoms.

	Mg	O
masses / g	0.24	0.16
find the number of moles of atoms by dividing the mass by the mass of 1 mole	0.24/24	0.16/16
number of moles of atoms	0.010	0.010
divide by the smaller number to find the ratio	0.010/0.010	0.010/0.010
ratio of moles	1	1
empirical formula	MgO	

The empirical formula of magnesium oxide is MgO.

THE FORMULA FOR COPPER OXIDE

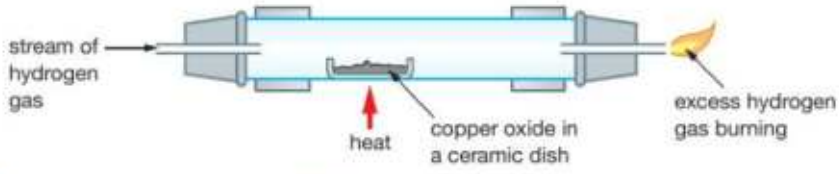
ACTIVITY 3

▼ PRACTICAL: INVESTIGATING THE FORMULA OF A METAL OXIDE BY REDUCTION

We can also find the formula of an oxide by removing the oxygen from it and looking at how the mass changes.

The following procedure can be used to find the formula of copper oxide:

- Weigh a ceramic dish.
- Put about 3 g of copper oxide in the ceramic dish and weigh the dish again.
- Place the ceramic dish in a tube as shown in Figure 5.13.
- Pass hydrogen gas over the copper oxide.
- Ignite the excess hydrogen, which comes out of the small hole in the boiling tube.
- Heat the copper oxide strongly until the reaction is finished (pink-brown copper metal will be seen).



▲ Figure 5.13 The experimental **set-up** for finding the formula of copper oxide.

A set of results for this practical could be:

mass of empty dish / g	23.78
mass of dish + copper oxide / g	26.96
mass of dish + contents at end of experiment / g	26.32

KEY POINT

This is a displacement (or competition) reaction. Hydrogen is more reactive than copper and displaces it from copper oxide. Displacement reactions are discussed in Chapter 11.

The reason that the mass decreases is because the hydrogen combines with the oxygen from the copper oxide to form water. The oxygen is removed from the copper oxide and we are left with only copper in the dish at the end of the experiment. Because oxygen is removed from the copper oxide we say that the copper oxide has been reduced. Reduction is explained in Chapter 11.

From this data we can calculate the mass of copper oxide at the beginning by subtracting the mass of the dish from the mass of the dish + copper oxide:

mass of copper oxide = 26.96 – 23.78 = 3.18 g

We can work out the mass of copper remaining at the end by subtracting the mass of the dish from the mass of the dish + copper at the end.

mass of copper = 26.32 – 23.78 = 2.54 g

The mass has decreased because the oxygen has been removed from the copper oxide and we can calculate the mass of oxygen by subtracting the mass of copper at the end from the mass of copper oxide:

mass of oxygen = 3.18 – 2.54 = 0.64 g

We now know that 2.54 g of copper combines with 0.64 g of oxygen in copper oxide and can deduce the empirical formula:

	Cu	O
masses / g	2.54	0.64
find the number of moles of atoms by dividing the mass by the mass of 1 mole	2.54/63.5	0.64/16
number of moles of atoms	0.0400	0.040
divide by the smaller number to find the ratio	0.0400/0.040	0.040/0.040
ratio of moles	1	1
empirical formula	CuO	

KEY POINT

The equation for the reaction that occurs in this experiment is:

$$CuO + H_2 \rightarrow Cu + H_2O$$

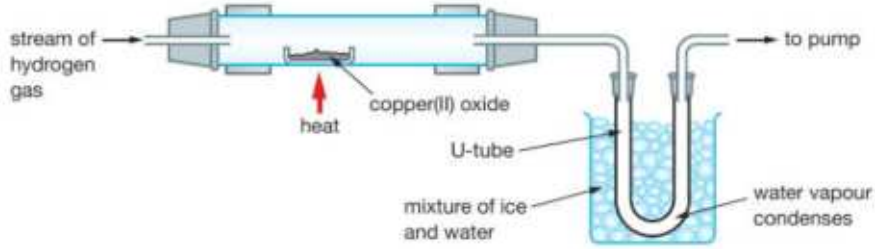
copper(II) oxide + hydrogen → copper + water

As well as a displacement reaction, this type of reaction can also be called a redox reaction. Redox reactions are discussed in Chapter 11.

Safety note: The teacher demonstrating needs to wear a face shield and use safety screens. The pupils require eye protection and should be no closer than 2 metres. If a drying agent is needed anhydrous calcium chloride should be used NOT concentrated sulfuric acid.

DETERMINING THE FORMULA OF WATER

We can modify the apparatus in Figure 5.13 to allow us to determine the formula of water.



▲ Figure 5.14 Apparatus that can be used to determine the formula of water.

The experiment is conducted in the same way except that this time the water vapour that is produced from the reaction between copper(II) oxide and hydrogen is condensed. The contents of the dish at the beginning and the end of the experiment are again weighed but this time the mass of water that collects in the U-tube must also be measured.

mass of empty dish / g	23.78
mass of dish + copper oxide / g	26.96
mass of dish + contents at end of experiment / g	26.32
mass of water / g	0.72

Here we are using the same results as above. The mass of oxygen lost from the copper(II) oxide is 0.64g.

All the oxygen lost from the copper(II) oxide combines with hydrogen to form water. This means that the water contains 0.64g of oxygen. 0.72g of water was collected so the mass of hydrogen in the water must be 0.72 – 0.64 = 0.08g. We can now determine the empirical formula of water:

	H	O
masses / g	0.08	0.64
number of moles of atoms	0.08/1	0.64/16
number of moles of atoms	0.08	0.040
divide by the smaller number to find the ratio	0.08/0.040	0.040/0.040
ratio of moles	2	1
empirical formula	H_2O	

WORKING OUT FORMULAE USING PERCENTAGE COMPOSITION FIGURES

In the worked examples and practical examples above, we have determined the empirical formulae of compounds using masses. However, we are often given percentages by mass instead of just masses.

EXAMPLE 5

Find the empirical formula of a compound containing 82.7% C and 17.3% H by mass (A_r of H = 1, A_r of C = 12).

The percentage figures apply to any amount of substance you choose, so let's choose 100 g. In this case the percentages convert simply into masses: 82.7% of 100 g is 82.7 g (Table 5.1).

Table 5.1 Finding the ratio from percentage by mass

	C	H
percentages / %	82.7	17.3
masses in 100 g / g	82.7	17.3
number of moles of atoms	82.7/12	17.3/1
number of moles	6.89	17.3
divide by smallest to get ratio	6.89/6.89	17.3/6.89
ratio of moles	1	2.5

From this we can see that there are 2.5 mol of H atoms for every mole of C atoms. The empirical formula, however, is the *whole number ratio* of the elements present in a compound. To obtain a whole number here we multiply both numbers by 2 to get C_2H_5, which is the empirical formula.

HINT

When you calculate 17.3/6.89 you actually obtain 2.51. When doing these calculations it is fine to round 2.51 to 2.5 or 1.01 to 1 but what you must not do is round 2.51 to 3!
If you got a ratio of C:H of 1:1.33 you would not round this down to 1:1 but rather multiply by 3 to obtain C_3H_4.

CONVERTING EMPIRICAL FORMULAE INTO MOLECULAR FORMULAE

When you have learned a bit more **organic chemistry** in Unit 4 you will realise that, in the example we have just looked at, C_2H_5 can't possibly be the real formula of the compound. The molecular formula (the actual number of each atom present in a molecule) has to be a multiple of C_2H_5, like C_4H_{10}.

We can find the molecular formula if we know the relative formula mass of the compound (or the mass of 1 mole, which is just the M_r in grams).

In the previous example, suppose you were told that the relative formula mass of the compound was 58.

C_2H_5 has a relative formula mass of 29 (A_r of H = 1, A_r of C = 12).

All you need to find out is how many times 29 goes into 58.

$$58/29 = 2$$

So you need 2 lots of C_2H_5, in other words, C_4H_{10}.

The molecular formula is C_4H_{10}.

EXAMPLE 6

A compound has the empirical formula CH_2. If the relative formula mass is 56, work out the molecular formula.

The relative formula mass of CH_2 is $12 + (2 \times 1) = 14$.

$$56/14 = 4$$

Therefore there must be 4 lots of CH_2 in the actual molecule and the molecular formula is C_4H_8.

Remember, the ratio of elements in the molecular formula must be the same as in the empirical formula: C_4H_8 cancels down to CH_2.

EMPIRICAL FORMULA CALCULATIONS INVOLVING WATER OF CRYSTALLISATION

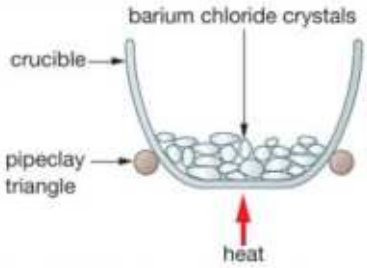
FINDING THE n IN $BaCl_2 \cdot nH_2O$

REMINDER

Remember that when some substances crystallise from solution, water becomes chemically bound up with the salt. This is called **water of crystallisation**. The salt is said to be **hydrated**.

REMINDER

Anhydrous means without water.



▲ Figure 5.15 Heating barium chloride crystals in a crucible

Safety note: Barium chloride is toxic but a Bunsen flame is not hot enough to release it into the atmosphere.

HINT

If you are doing this experiment, how can you be sure that all the water has been driven off? The best way to do this is to heat it to constant mass. You heat the crucible and weigh it. Keep doing this until the mass remains constant. If the mass has gone down after heating there may still be water present, but when the mass remains constant after heating you know that all the water has been driven off.

Usually, when you heat a salt that contains water of crystallisation, the water is driven off, leaving the **anhydrous** salt behind. Hydrated barium chloride is a commonly used example because the barium chloride itself doesn't decompose even on quite strong heating.

If you heated barium chloride crystals in a crucible you might obtain these results:

Mass of crucible = 30.00 g

Mass of crucible + barium chloride crystals, $BaCl_2 \cdot nH_2O$ = 32.44 g

Mass of crucible + anhydrous barium chloride, $BaCl_2$ = 32.08 g

To find n, you need to find the ratio of the number of moles of $BaCl_2$ to the number of moles of water. It's just another empirical formula calculation (A_r of H = 1, A_r of O = 16, A_r of Cl = 35.5, A_r of Ba = 137).

Mass of $BaCl_2$ = 32.08 – 30.00 = 2.08 g

Mass of water = 32.44 – 32.08 = 0.36 g

Table 5.2 Finding the n in $BaCl_2 \cdot nH_2O$

	$BaCl_2$	H_2O
masses / g	2.08	0.36
divide by M_r to find the number of moles	2.08/208	0.36/18
number of moles	0.0100	0.020
ratio of moles	1	2
empirical formula	$BaCl_2 \cdot 2H_2O$	

CALCULATIONS USING MOLES, CHEMICAL EQUATIONS AND MASSES OF SUBSTANCES

INTERPRETING SYMBOLS IN EQUATIONS IN TERMS OF MOLES

KEY POINT

The big numbers in front of the formulae tell us the number of moles of each substance that react. Although there does not appear to be a big number in front of the CH_4 and CO_2, there should actually be a '1' in front of each but we just don't write it.

If we write a chemical equation:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

we can say that 1 molecule of CH_4 combines with 2 molecules of O_2 to form 1 molecule of CO_2 and 2 molecules of water. When doing calculations, however, it is often more useful to think about this in terms of moles and take symbols as meaning moles of each substance. So here we can say:

1 mol CH_4 reacts with 2 mol O_2 to form 1 mol CO_2 and 2 mol H_2O

We have not changed the meaning of the equation as the ratios are still the same.

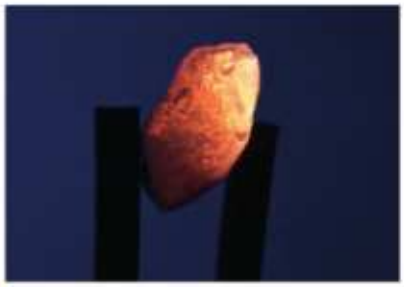
KEY POINT

Remember that 2 mol of O_2 contains twice as many molecules as 1 mol of CH_4.

We can therefore tell from this equation that 16 g of CH_4 (1 mol) reacts exactly with 64 g of O_2 (2 mol) to form 44 g of CO_2 (1 mol) and 36 g of H_2O (2 mol).

CALCULATIONS INVOLVING ONLY MASSES

Typical calculations will give you a mass of starting material and ask you to calculate how much product you are likely to obtain. You will also find examples done in reverse, where you are told the mass of the product and are asked to find out how much of the starting material you would need. In almost all the cases you will see at International GCSE you will be given the equation for the reaction.



▲ Figure 5.16 A glowing piece of limestone. Limestone is impure calcium carbonate – it decomposes when heated to form calcium oxide (quicklime) and carbon dioxide. This is a thermal **decomposition reaction**.

A PROBLEM INVOLVING HEATING CALCIUM CARBONATE

When calcium carbonate, $CaCO_3$, is heated, calcium oxide is formed. Imagine you wanted to calculate the mass of calcium oxide produced by heating 25 g of calcium carbonate (A_r: C = 12, O = 16, Ca = 40).

$$CaCO_3 \rightarrow CaO + CO_2$$

THE CALCULATION

The method we will use has three steps:

Step 1: Calculate the number of moles using the mass that you have been given.

Step 2: Use the chemical equation to work out the number of moles of the substance you are interested in.

Step 3: Convert the number of moles to a mass.

KEY POINT

The M_r of $CaCO_3$ is 100 and the M_r of CaO is 56.

In this reaction we have 25 g of $CaCO_3$ and the number of moles can be calculated as:

$$\text{number of moles} = \frac{\text{mass}}{\text{mass of 1 mole}} = \frac{25}{100} = 0.25\,\text{mol}$$

The chemical equation for this reaction is

$$CaCO_3 \rightarrow CaO + CO_2$$

We can see from the equation that 1 mole of $CaCO_3$ will decompose to produce 1 mole of CaO. In other words, the equation is telling us that if we start with a certain number of moles of $CaCO_3$ we will obtain the same number of moles of CaO at the end.

Therefore, we can deduce that 0.25 mol $CaCO_3$ will decompose to produce 0.25 mol CaO. Now that we know the number of moles of CaO (M_r = 56) we can convert this to a mass:

$$\text{mass} = \text{number of moles} \times \text{mass of 1 mole}$$

$$\text{mass} = 0.25 \times 56 = 14\,\text{g}$$

Therefore, the reaction will produce 14 g of calcium oxide.

ALTERNATIVE METHOD

The calculation can also be done in a different way using ratios:

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Interpret the equation in terms of moles:

1 mol $CaCO_3$ produces 1 mol CaO (and 1 mol CO_2)

Substitute masses where relevant:

100 g (1 mol) $CaCO_3$ produces 56 g (1 mol) CaO

Do a proportion calculation:

If 100 g of calcium carbonate gives 56 g of calcium oxide

1 g of calcium carbonate gives $\frac{56}{100}$ g of calcium oxide = 0.56 g

25 g of calcium carbonate gives 25 × 0.56 g of calcium oxide = 14 g of calcium oxide

HINT

You do not have to learn both methods, just learn whichever method you are happier with.
Your maths may be so good that you don't need to take all these steps to find the answer. If you can do it more quickly, that's fine. However, you must still show all your calculations.
When you have finished a chemistry calculation, the impression should nearly always be that there are a lot of words with a few numbers between them, not vice versa.

A PROBLEM ABOUT EXTRACTING IRON

The equation below is for a reaction that occurs in the extraction of iron:

$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$

Calculate the mass of iron which can be formed from 1000 g of iron oxide.

We are given the mass of Fe_2O_3 in the question and so we can calculate the number of moles of Fe_2O_3:

$$\text{number of moles} = \frac{\text{mass}}{\text{mass of 1 mole}}$$

$$\text{number of moles} = \frac{1000}{160} = 6.25 \text{ mol}$$

From the chemical equation we can see that 1 mol Fe_2O_3 produces 2 mol Fe. We know this because of the big numbers in front of the formulae.

So we know that, if we start with a certain number of moles of Fe_2O_3, we will obtain twice as many moles of Fe.

So 6.25 mol Fe_2O_3 produces 2 × 6.25 = 12.5 mol Fe:

mass = number of moles × mass of 1 mole

The mass of 12.5 mol Fe is 12.5 × 56 = 700 g.

KEY POINT

The A_r of Fe is 56.
The M_r of Fe_2O_3 = 2 × 56 + 3 × 18 = 160.

HINT

To find the mass of Fe we multiply the number of moles of Fe by the mass of 1 mole of Fe (56 g). A common mistake is to multiply the number of moles by the mass of 2Fe (112 g), but we have already used the '2' when we worked out the number of moles of Fe.

ALTERNATIVE METHOD IN TERMS OF RATIOS

First interpret the equation in terms of moles:

1 mol Fe_2O_3 reacts with C to form 2 mol Fe (and CO_2).

We are only looking at how much iron is produced, so let's introduce just these masses.

160 g (1 mol) of Fe_2O_3 produces 2 × 56 g (2 mol) of Fe.

That is, 160 g of Fe_2O_3 produces 112 g of Fe.

From this we can calculate that 1 g of Fe_2O_3 will produce 112/160 g of Fe, and therefore 1000 g of Fe will produce 1000 × 112/160 = 700 g.

A PROBLEM INVOLVING THE EXTRACTION OF LEAD

Lead is extracted from galena, PbS. The **ore** is roasted in air to produce lead(II) oxide, PbO:

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$

The lead(II) oxide is then converted to lead by heating it with carbon in a blast furnace:

$$PbO(s) + C(s) \rightarrow Pb(l) + CO(g)$$

The molten lead is tapped from the bottom of the furnace.

Calculate the mass of lead that would be produced from 1 tonne of galena.

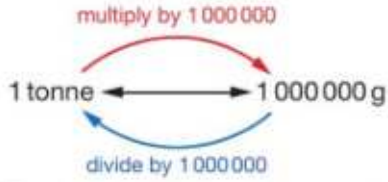
(A_r: O = 16, S = 32, Pb = 207)



▲ Figure 5.17 Molten lead tapped from the bottom of a furnace.

HINT

You should be told how many grams there are in a tonne if you need this information in the exam.



▲ Figure 5.18 How to convert between grams and tonnes

HINT

1 000 000 might be given to you as 10^6 or 1×10^6. These are both the same.

We have been given the mass of PbS so we can calculate the number of moles. However, we have to be careful because the mass is in tonnes but to calculate a number of moles we need to know the mass in grams, so we must convert tonnes to grams. The conversion for this is shown in Figure 5.18. Just write down this relationship: *1* tonne is equivalent to *1 000 000* g so, to change from tonnes to grams, the number has to *increase* (from 1 to 1 000 000), so we *multiply* by 1 000 000.

Therefore we have 1 000 000 g PbS.

$$\text{Number of moles} = \frac{\text{mass}}{\text{mass of 1 mole}}$$

$$\text{The number of moles of PbS} = \frac{1\,000\,000}{239} = 4184 \text{ mol.}$$

From the first equation:

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$

we can see that 2 mol PbS produce 2 mol PbO, therefore we can work out that 4184 mol PbS will produce 4184 mol PbO.

From the second equation:

$$PbO(s) + C(s) \rightarrow Pb(l) + CO(g)$$

we can see that 1 mol PbO produces 1 mol Pb. But we are starting this reaction with 4184 mol PbO and so we can work out that we will produce 4184 mol Pb.

The mass of 4184 mol Pb is $4184 \times 207 = 866\,000$ g.

We can convert this to tonnes by dividing by 1 000 000:

$$866\,000/1\,000\,000 = 0.866 \text{ tonne}$$

ALTERNATIVE METHOD

KEY POINT

We've doubled the second equation so that we can trace what happens to all the 2PbO from the first one.
This could also be simplified to 1 mol PbS produces 1 mol Pb. This would save you doing some arithmetic as you would not have to multiply everything by 2. However, in the end it does not make any difference to the answer, so you do not have to simplify it if you don't want to.

HINT

There are advantages and disadvantages of both methods.
For the first method, we can use the same three steps in more advanced work that you might meet at the next level. However, a bit more maths will be involved: converting tonnes to grams and back again. The alternative method has fewer steps but we cannot use it in the same way when doing some of the calculations you will meet if you continue with Chemistry.

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$

$$PbO(s) + C(s) \rightarrow Pb(l) + CO(g)$$

Interpret the equation in terms of moles and trace the lead through the equations:

2 mol PbS produces 2 mol PbO

If we double the second equation:

$$2PbO(s) + 2C(s) \rightarrow 2Pb(l) + 2CO(g)$$

we can see that 2 mol PbO produces 2 mol Pb.

In other words, every 2 mol of PbS produces 2 mol of Pb.

Substitute masses where relevant. In this case, the relevant masses are only the PbS and the Pb:

2×239 g PbS produces 2×207 g Pb

478 g PbS produces 414 g Pb

Now there seems to be a problem. The question is asking about tonnes and not grams. You could calculate how many grams there are in a tonne. However, it's much easier to think a bit, and realise that the ratio is always going to be the same, whatever the units, which means that:

478 tonnes PbS produces 414 tonnes Pb

Do the proportion calculation:

If 478 tonnes PbS produces 414 tonnes Pb

then 1 tonne PbS gives $\frac{417}{478}$ tonne Pb = 0.866 tonne

0.866 tonne of lead is produced from 1 tonne of galena.

CALCULATING PERCENTAGE YIELDS

WHAT IS A PERCENTAGE YIELD?

If you calculate how much product a reaction might produce, in real life you rarely obtain as much as you expected. If you expect to get 100 g, but only get 80 g, your percentage **yield** is 80%. The rest of it has been lost in some way. This could be due to spillages, or losses when you transfer a liquid from one container to another. Or it may be that there are all sorts of side reactions going on, so that some of your starting materials are changed into unwanted products. That happens a lot during reactions in organic chemistry.



Figure 5.19 Experiments done by students to make and purify organic compounds rarely give a high percentage yield.

CALCULATING THE PERCENTAGE YIELD

HINT

The percentage yield should always come out as less than 100%. If it comes out as more than 100% either you have made a mistake in the calculation or the question will continue by asking about what might have gone wrong in the experiment to give a value greater than 100%. If you are making a salt (see Chapter 13), for instance, a possible reason you could get a percentage yield greater than 100% is that it was not completely dry.

Suppose you do a calculation and work out that you should get 12.5 g of copper sulfate crystals, but you only get 11.2 g when you actually do the experiment. 12.5 g is the *theoretical yield* and can be obtained by carrying out a moles calculation. 11.2 g is the *actual yield* – this is what is obtained in the actual experiment and will be given to you in the question.

$$\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

The percentage yield is $\frac{11.2}{12.5} \times 100 = 89.6\%$.

EXAMPLE 7

A student reacted 2.40 g of copper(II) oxide (CuO) with hot sulfuric acid. She made 5.21 g of copper(II) sulfate crystals ($CuSO_4 \cdot 5H_2O$).

The equations for the reactions are:

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

$$CuSO_4(aq) + 5H_2O(l) \rightarrow CuSO_4 \cdot 5H_2O(l)$$

First we need to calculate the theoretical yield. This is done by carrying out a moles calculation. We have enough information to calculate the number of moles of copper(II) oxide:

$$\text{number of moles of CuO} = \frac{2.40}{79.5} = 0.0302\,\text{mol}$$

From the first equation we can deduce that 0.0302 mol CuO will produce 0.0302 mol $CuSO_4$.

From the second equation we can deduce that 0.0302 mol $CuSO_4$ will produce 0.0302 mol $CuSO_4 \cdot 5H_2O$.

Now we need to calculate the mass of $CuSO_4 \cdot 5H_2O$ by multiplying the number of moles by the mass of 1 mole:

$$\text{mass} = 0.0302 \times 249.5 = 7.53\,\text{g}$$

This is the theoretical yield of copper(II) sulfate crystals.

The actual yield is what was obtained in the experiment. This was 5.21 g.

The percentage yield = (actual yield/theoretical yield) × 100

The percentage yield is 5.21/7.53 × 100 = 69.2%.

CALCULATIONS IN WHICH YOU HAVE TO CALCULATE WHICH SUBSTANCE IS IN EXCESS

When you make something in the lab, you rarely mix things together in exactly the right proportions. Usually, something is in **excess**, and you remove the excess (by filtering, for example) when the reaction is complete. If something is in excess there is more than enough of it to react with the other substance and so we don't need to worry about it.

In all the examples we have done above, we have only ever been given enough information to calculate the number of moles of one thing at the beginning of the problem. We have used this number of moles throughout the calculations. But what would happen if we were given the following question?

Magnesium reacts with hydrochloric acid according to the following equation:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

0.2 mol Mg is reacted with 0.2 mol HCl. Calculate the mass of hydrogen gas produced.

We might be tempted to say that 0.2 mol Mg produces 0.2 mol H_2(g) and the mass of $H_2 = 0.2 \times 2 = 0.4$ g. Unfortunately this is not the correct answer!

We can understand why it is not correct by looking at the chemical equation. 1 mol Mg reacts with 2 mol HCl and therefore 0.2 mol Mg would react with $2 \times 0.2 = 0.4$ mol HCl.

But we only used 0.2 mol HCl and so we did not have enough to react with all the Mg. Because all the Mg did not react we cannot use the number of moles of Mg to work out how much hydrogen is produced.

If we try starting with the number of moles of HCl, we can deduce from the chemical equation that 2 mol HCl reacts with 1 mol Mg, therefore 0.2 mol HCl reacts with 0.1 mol Mg. We added 0.2 mol Mg and so there is more than enough to react with all the HCl – the Mg is in excess.

KEY POINT

You always have to use the chemical equation to determine which substance is in excess. If we had been given 0.2 mol Mg and 0.3 mol HCl in this reaction it would look like the HCl is in excess because there is more of it. But if you look at the chemical equation you can see that 0.3 mol HCl only reacts with 0.15 mol Mg so there is still not enough HCl to react with all the Mg, so the Mg is still in excess.

Because we know that all the HCl reacts we can use the number of moles of HCl to work out how much H_2 is produced.

2 mol HCl produce 1 mol H_2: the number of moles of H_2 is half the number of moles of HCl.

Therefore 0.2 mol HCl produce 0.1 mol H_2.

The mass of $H_2 = 0.1 \times 2 = 0.2$ g.

This is the correct answer!

To deduce which substance is in excess we try both numbers of moles in the chemical equation and compare the numbers.

EXAMPLE 8

Copper reacts with concentrated nitric acid according to the equation:

$$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2H_2O(l) + 2NO_2(g)$$

3.2 g of copper is reacted with 0.40 mol concentrated nitric acid. Work out which reagent is in excess.

We need to convert the mass of Cu to a number of moles:

$$\text{number of moles of Cu} = \frac{3.2}{63.5} = 0.050 \text{ mol}$$

Looking at the chemical equation we can see that 1 mol Cu reacts with 4 mol HNO_3, so we can calculate that:

0.050 mol Cu reacts with $4 \times 0.050 = 0.20$ mol HNO_3

We have more than 0.20 mol HNO_3 therefore HNO_3 is in excess.

If the question went further and asked us to calculate the amount in moles of NO_2 produced using these quantities we would have to use the number of moles of Cu because not all the HNO_3 is used up. We would obtain $2 \times 0.050 = 0.10$ mol NO_2.

KEY POINT

A reagent is just something that reacts.

CHAPTER QUESTIONS

SKILLS PROBLEM SOLVING

1 Balance the following equations:

a $Fe + HCl \rightarrow FeCl_2 + H_2$

b $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

c $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$

d $Al + Cr_2O_3 \rightarrow Al_2O_3 + Cr$

e $Fe_2O_3 + CO \rightarrow Fe + CO_2$

f $NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$

g $C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$

h $Fe_3O_4 + H_2 \rightarrow Fe + H_2O$

i $Pb + AgNO_3 \rightarrow Pb(NO_3)_2 + Ag$

j $AgNO_3 + MgCl_2 \rightarrow Mg(NO_3)_2 + AgCl$

k $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

2 Calculate the relative formula masses of the following compounds:

a CO_2

b CH_3CO_2H

c Na_2SO_4

d $(NH_4)_2SO_4$

e $Na_2CO_3 \cdot 10H_2O$

f $Cr_2(SO_4)_3$

(A_r: H = 1, C = 12, N = 14, O = 16, Na = 23, S = 32, Ca = 40, Cr = 52, Fe = 56)

3 Calculate the percentage of nitrogen in each of the following substances (all used as nitrogen fertilisers):

a potassium nitrate, KNO_3

b ammonium nitrate, NH_4NO_3

c ammonium sulfate, $(NH_4)_2SO_4$

(A_r: H = 1, N = 14, O = 16, S = 32, K = 39)

4 Calculate the mass of the following:

a 1 mol of HCN

b 1 mol of lead(II) nitrate, $Pb(NO_3)_2$

c 4.30 mol of methane, CH_4

d 0.70 mol of Na_2O

e 0.015 mol of $NaNO_3$

f 0.24 mol of sodium carbonate crystals, $Na_2CO_3 \cdot 10H_2O$

(A_r: H = 1, C = 12, N = 14, O = 16, Na = 23, Pb = 207)

SKILLS PROBLEM SOLVING



5 Calculate the number of moles represented by each of the following:

a 20 g of magnesium oxide, MgO

b 3.20 g of iron(III) oxide, Fe_2O_3

c 2 kg of copper(II) oxide, CuO

d 50 g of copper(II) sulfate crystals, $CuSO_4 \cdot 5H_2O$

e 1 tonne of iron, Fe (1 tonne is 1 000 000 g)

f 0.032 g of sulfur dioxide, SO_2

(A_r: H = 1, O = 16, S = 32, Mg = 24, Fe = 56, Cu = 63.5)

6 The following calculations use A_r: H = 1, O = 16, Na = 23, Cl = 35.5, Ca = 40, Cu = 63.5.

a Calculate the mass of 4 mol of sodium chloride, NaCl.

b Calculate how many moles is 37 g of calcium hydroxide, $Ca(OH)_2$.

c Calculate how many moles is 1 kg (1000 g) of calcium, Ca.

d Calculate the mass of 0.125 mol of copper(II) oxide, CuO.

e 0.1 mol of a substance has a mass of 4 g. Calculate the mass of 1 mole.

f 0.004 mol of a substance has a mass of 1 g. Calculate the relative formula mass of the compound.

7 Determine the empirical formulae of the compounds which contain:

a 9.39 g P, 0.61 g H

b 5.85 g K, 2.10 g N, 4.80 g O

c 3.22 g Na, 4.48 g S, 3.36 g O

d 22.0% C, 4.6% H, 73.4% Br (by mass)

(A_r: H = 1, C = 12, N = 14, O = 16, Na = 23, S = 32, K = 39, Br = 80)

8 1.24 g of phosphorus was burned completely in oxygen to give 2.84 g of phosphorus oxide. Find:

a the empirical formula of the oxide

b the molecular formula of the oxide given that 1 mole of the oxide has a mass of 284 g.

(A_r: O = 16, P = 31)

9 An organic compound contained C 66.7%, H 11.1%, O 22.2% by mass. Its relative formula mass was 72. Find:

a the empirical formula of the compound

b the molecular formula of the compound.

(A_r: H = 1, C = 12, O = 16)

10 In an experiment to find the number of molecules of water of crystallisation in sodium sulfate crystals, $Na_2SO_4 \cdot nH_2O$, 3.22 g of sodium sulfate crystals were heated gently. When all the water of crystallisation had been driven off, 1.42 g of anhydrous sodium sulfate was left. Find the value of n in the formula. (A_r: H = 1, O = 16, Na = 23, S = 32)

SKILLS PROBLEM SOLVING



11 Gypsum is hydrated calcium sulfate, $CaSO_4 \cdot nH_2O$. A sample of gypsum was heated in a crucible until all the water of crystallisation had been driven off. The following results were obtained:

Mass of crucible = 37.34 g

Mass of crucible + gypsum, $CaSO_4 \cdot nH_2O$ = 45.94 g

Mass of crucible + anhydrous calcium sulfate, $CaSO_4$ = 44.14 g

Calculate the value of n in the formula $CaSO_4 \cdot nH_2O$.

(A_r: H = 1, O = 16, S = 32, Ca = 40)

12 **a** Calculate the amount in moles of SO_3 formed when 0.36 mol SO_2 reacts with excess O_2.

$2SO_2 + O_2 \rightarrow 2SO_3$

b Calculate the amount in moles of HCl that reacts with 0.4 mol $CaCO_3$.

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

c Calculate the amount in moles of H_2S formed when 0.4 mol of HCl reacts with excess Sb_2S_3.

$Sb_2S_3 + 6HCl \rightarrow 2SbCl_3 + 3H_2S$

d Calculate the amount in moles of iron formed when 0.9 mol carbon monoxide reacts with excess iron(III) oxide.

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

e Calculate the amount in moles of hydrogen that would be required to make 0.8 mol NH_3.

$N_2 + 3H_2 \rightarrow 2NH_3$

13 The reaction between iron and bromine is

$2Fe + 3Br_2 \rightarrow 2FeBr_3$

10 g of iron is reacted with bromine.

a Calculate the amount in moles of iron that reacted.

b Calculate the amount in moles of bromine that the iron reacted with.

c Calculate the amount in moles of $FeBr_3$ that will be formed.

d Calculate the mass of $FeBr_3$ formed.

(A_r: Fe = 56, Br = 80)

14 Titanium is manufactured by heating titanium(IV) chloride with sodium.

$TiCl_4(g) + 4Na(l) \rightarrow Ti(s) + 4NaCl(s)$

1.0 g of $TiCl_4$ is reacted with excess sodium

(A_r: Na = 23, Ti = 48, Cl = 35.5)

a Calculate the amount in moles of $TiCl_4$ reacted.

b Calculate the amount in moles of Ti formed.

c Calculate the mass of Ti formed.

d Calculate the mass of NaCl formed.

e Calculate the mass of Ti formed when 1 tonne of $TiCl_4$ reacts with excess sodium (1 tonne is 1 000 000 g).

SKILLS PROBLEM SOLVING

15 2.67 g of aluminium chloride was dissolved in water and an excess of silver nitrate solution was added to give a precipitate of silver chloride (AgCl).

$$AlCl_3(aq) + 3AgNO_3(aq) \rightarrow Al(NO_3)_3(aq) + 3AgCl(s)$$

Calculate the mass of silver chloride that would be formed.

(A_r: Al = 27, Cl = 35.5, Ag = 108)

16 Chromium is manufactured by heating a mixture of chromium(III) oxide with aluminium powder.

$$Cr_2O_3(s) + 2Al(s) \rightarrow 2Cr(s) + Al_2O_3(s)$$

a Calculate the mass of aluminium needed to react with 50 g of Cr_2O_3.

b Calculate the mass of chromium produced from 50 g of Cr_2O_3.

c Calculate the mass of chromium produced from 5 kg of Cr_2O_3.

d Calculate the mass of chromium produced from 5 tonnes of Cr_2O_3.

(1 tonne is 1 000 000 g)

(A_r: Cr = 52, O = 16, Al = 27)

17 Copper(II) sulfate crystals, $CuSO_4 \cdot 5H_2O$, can be made by heating copper(II) oxide with dilute sulfuric acid and then crystallising the solution formed.

a Calculate the maximum mass of crystals that could be made from 4.00 g of copper(II) oxide using an excess of sulfuric acid.

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

$$CuSO_4(aq) + 5H_2O(l) \rightarrow CuSO_4 \cdot 5H_2O(s)$$

b If the actual mass of copper(II) sulfate collected at the end of the experiment was 11.25 g, calculate the percentage yield.

(A_r: H = 1, O = 16, S = 32, Cu = 63.5)

18 Ethanol reacts with ethanoic acid to form ethyl ethanoate and water:

$$C_2H_5OH(l) + CH_3COOH(l) \rightarrow CH_3COOC_2H_5(l) + H_2O(l)$$

ethanol ethanoic acid ethyl ethanoate water

a Calculate the mass of ethyl ethanoate produced when 20.0 g of ethanol reacts with excess ethanoic acid.

b The actual yield in this experiment is 30.0 g of ethyl ethanoate. Calculate the percentage yield.

(A_r: C = 12, H = 1, O = 16)

SKILLS REASONING

19 Determine which reactant is in excess in each case.

a 0.5 mol of Na_2CO_3 is reacted with 0.5 mol hydrochloric acid:

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

b 0.01 mol C_3H_8 is reacted with 0.02 mol O_2:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

c 28 g CO is reacted with 0.6 mol Fe_2O_3:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

d 16 g O_2 is reacted with 16 g SO_2:

$$2SO_2 + O_2 \rightarrow 2SO_3$$

(A_r : C = 12, O = 16, S = 32)

20 1.0 g of $CaCO_3$ is reacted with 0.015 mol of HCl:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

a Determine which reagent is present in excess.

SKILLS PROBLEM SOLVING

b Calculate the mass of CO_2 produced.

(A_r: Ca = 40, C = 12, O = 16)

6 IONIC BONDING

We have already looked at the definition of a compound. A compound is formed when two or more elements chemically combine. In this chapter we are going to look at one way in which elements can chemically combine: by the transfer of electrons to form ionic compounds.



▲ Figure 6.1 The properties of a compound are very different from those of the elements. Sodium (an element) is a dangerously reactive metal. It is stored under oil to prevent it reacting with air or water. Chlorine (an element) is a very poisonous, reactive gas. But salt, sodium chloride (an ionic compound), is safe to eat in small quantities.

LEARNING OBJECTIVES

- Understand how ions are formed by electron loss or gain
- Know the charges of these ions:
  - metals in Groups 1, 2 and 3
  - non-metals in Groups 5, 6 and 7
  - Ag^+, Cu^{2+}, Fe^{2+}, Fe^{3+}, Pb^{2+}, Zn^{2+}
  - hydrogen (H^+), hydroxide (OH^-), ammonium (NH_4^+), carbonate (CO_3^{2-}), nitrate (NO_3^-), sulfate (SO_4^{2-})
- Write formulae for compounds formed between the ions listed above
- Draw dot-and-cross diagrams to show the formation of ionic compounds by electron transfer, limited to combinations of elements from Groups 1, 2, 3, 5, 6 and 7 *(only outer electrons need be shown)*
- Understand ionic bonding in terms of electrostatic attractions
- Understand why compounds with giant ionic lattices have high melting and boiling points
- Know that ionic compounds do not conduct electricity when solid, but do conduct electricity when molten and in aqueous solution

IONIC BONDING

Sodium chloride is probably the best-known example of an ionic compound – one that is held together by **ionic bonding**. There are lots of other ionic compounds, such as magnesium oxide, calcium fluoride and zinc bromide. What you will realise about all these compounds is that they all contain a metal combined with a non-metal.

You can recognise ionic compounds because they (usually) contain a metal.

HINT

There are one or two exceptions to this: there are ionic compounds that do not contain a metal, for example those containing the ammonium ion (such as NH_4Cl, $(NH_4)_2SO_4$. We will look at these later.

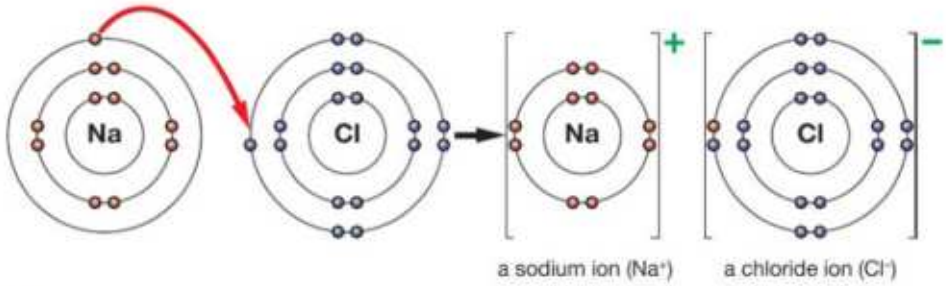
KEY POINT

This is a simplification! In reality, you don't react sodium with chlorine atoms, but with chlorine molecules, Cl_2.

KEY POINT

You can check that sodium does have a positive charge. If you look at the Periodic Table you will see that sodium has an atomic number of 11, so it has 11 protons in its nucleus. Protons have a positive charge so the charge on the nucleus is 11+. In the sodium **atom** there are 11 electrons, each with a negative charge. These cancel out the 11+ on the nucleus and there is no overall charge. However, in the sodium ion there are only 10 electrons, so with 11+ and 10– there is an overall charge of 1+.

When a non-metal such as chlorine combines with a metal such as sodium, the chlorine atom has a stronger attraction for electrons than the sodium atom and *an electron is transferred from the outer shell of the sodium atom to the outer shell of the chlorine atom*. Because an electron has a negative charge, when something gains an electron it becomes negatively charged, and when something loses an electron it becomes positively charged.



▲ Figure 6.2 Ionic bonding in sodium chloride. Ionic bonding involves the transfer of electron(s).

The charged particles that are formed are called **ions**.

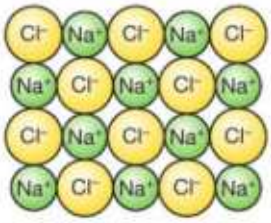
Ions are charged particles formed when atoms (or groups of atoms) lose or gain electrons. Ions can have either a positive or a negative charge.

- A positive ion is called a **cation**, for example Na^+.
- A negative ion is called an **anion**, for example Cl^-.

KEY POINT

Electrostatic attraction simply means that positively charged particles attract negatively charged particles.

When an ionic compound is formed, electron(s) are transferred from a metal atom to a non-metal atom to form positive and negative ions. Ionic compounds have ionic bonding. *Ionic bonding is the strong* **electrostatic attraction** *between positive and negative ions.*

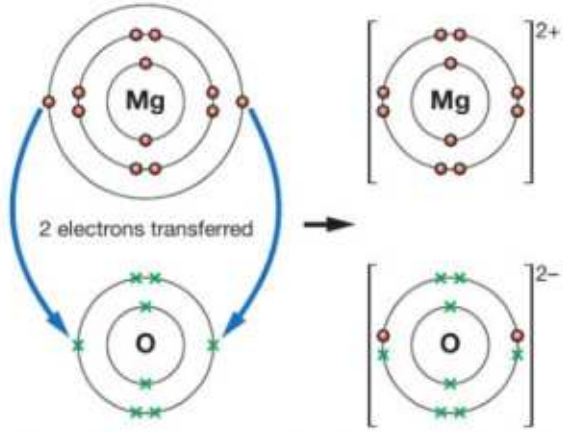


▲ Figure 6.3 Part of the structure of a sodium chloride crystal. The structure is held together by the attraction between positive and negative ions.

Ionic bonding is often shown using **dot-and-cross diagrams**. Figure 6.4 is an example of a dot-and-cross diagram. Although the electrons are drawn as dots or as crosses, there is absolutely no difference between them in reality. The dots and the crosses simply show that the electrons have come from two different atoms. You could equally well use two different coloured dots (as in Figure 6.2), or two different coloured crosses.

IONIC BONDING IN MAGNESIUM OXIDE

A dot-and-cross diagram for MgO is shown in Figure 6.4.

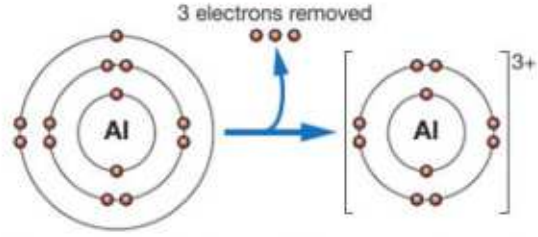


▲ Figure 6.4 A dot-and-cross diagram for magnesium oxide. When drawing these diagrams, don't forget the charges on the ions.

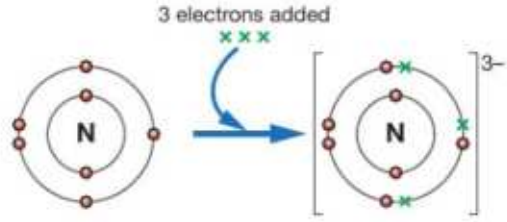
Two electrons are transferred from a magnesium atom to an oxygen atom to form Mg^{2+} and O^{2-} ions.

THE SIGNIFICANCE OF NOBLE GAS ELECTRONIC CONFIGURATIONS IN IONIC BONDING

If you look at the electronic arrangements of the ions formed in Figures 6.2, 6.4, 6.5 and 6.6, each of them has a noble gas electronic configuration: [2, 8] (the same as neon) or [2, 8, 8] (the same as argon). For the first 20 elements, atoms lose or gain electrons so that they achieve a noble gas electronic configuration. The elements in Groups 1, 2 and 3 of the Periodic Table will lose their outer shell electrons to form 1+, 2+ and 3+ ions, and the elements in Groups 5, 6 and 7 will gain electrons to form 3–, 2– and 1– ions.



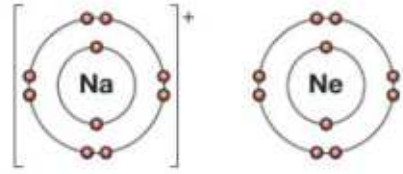
▲ Figure 6.5 An aluminium atom loses its 3 outer shell electrons to form an Al^{3+} ion.



▲ Figure 6.6 A nitrogen atom gains 3 electrons to form the nitride ion (N^{3-}).

KEY POINT

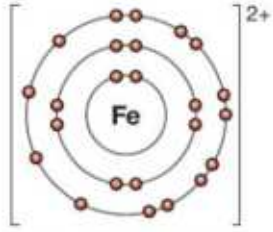
We sometimes use the word **isoelectronic**, which means 'have the same number of electrons'. So, when sodium forms an ion (electronic configuration [2, 8]) it becomes isoelectronic with neon [2, 8].



▲ Figure 6.7 Na^+ and Ne are isoelectronic – they have the same number of electrons.

Elements in Groups 1, 2, 6 and 7 always form ions that are **isoelectronic** with the nearest noble gas atom. For example, rubidium (Rb), which is in Group 1, has 1 electron in its outer shell and will lose this outer shell electron to form a 1+ ion, which has the same number of electrons as a krypton (Kr) atom. Iodine is in Group 7, so it has 7 electrons in its outer shell; it will gain 1 electron when it forms an ion to form a 1– ion. This 1– ion has the same number of electrons as a xenon (Xe) atom.

However, there are a lot of common ions that don't have noble gas structures. Fe^{2+}, Fe^{3+}, Cu^{2+}, Zn^{2+}, Ag^+ and Pb^{2+} are all ions that you will come across during the International GCSE course, although you won't have to write their electronic structures. Not one of them has a noble gas structure.

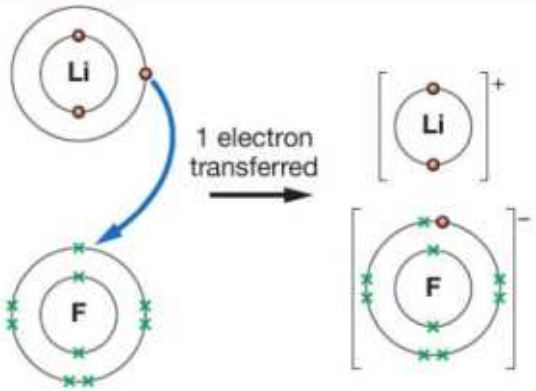


▲ Figure 6.8 An Fe^{2+} ion – definitely not a noble gas structure!

OTHER EXAMPLES OF IONIC BONDING

Ionic bonds are usually formed only if small numbers of electrons need to be transferred, typically 1 or 2, but occasionally 3.

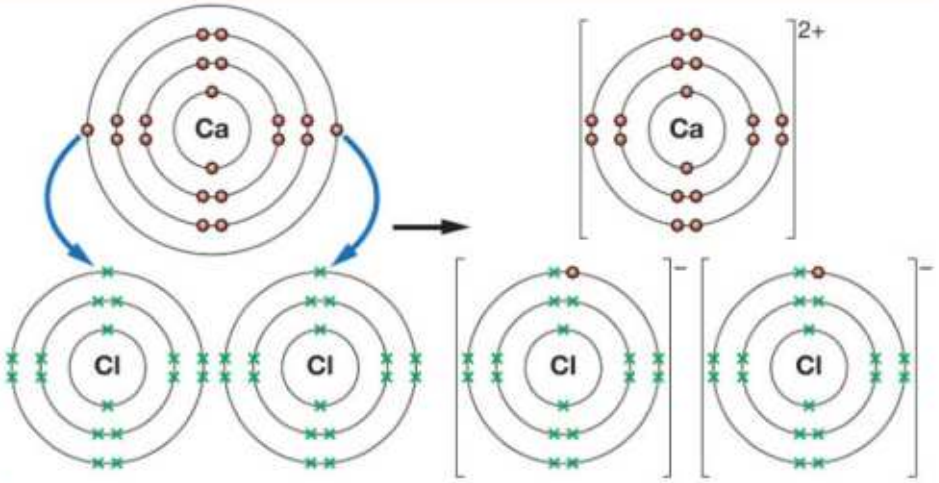
LITHIUM FLUORIDE



▲ Figure 6.9 A dot-and-cross diagram for lithium fluoride

The lithium atom has 1 electron in its outer shell that is easily lost, and the fluorine has space to receive one. One electron is transferred from the lithium atom to the fluorine atom. Lithium fluoride is held together by the strong electrostatic attractions between positive lithium (Li^+) ions and the negative fluoride (F^-) ions.

CALCIUM CHLORIDE



▲ Figure 6.10 A dot-and-cross diagram to show the formation of calcium chloride.

The calcium atom [2, 8, 8, 2] has 2 electrons in its outer shell but each chlorine atom [2, 8, 7] only has room in its outer shell to take one of them. You need two chlorines for every calcium. The 2 electrons are transferred from the outer shell of a calcium atom to two chlorine atoms, one to each. The formula for calcium chloride is therefore $CaCl_2$. There will be very strong electrostatic attractions holding the ions together because of the 2+ charge on the calcium ions.

FORMULAE FOR IONIC COMPOUNDS

There are so many different ionic compounds that you might encounter at International GSCE that it would be impossible to learn all their formulae. You need a simple way to work them out. You could work out a few from first principles, using their electronic structures, but that would take ages. Others would be too difficult. You need a simple, shortcut method.

THE NEED FOR EQUAL NUMBERS OF PLUSES AND MINUSES

Ions are formed when atoms, or groups of atoms, lose or gain electrons. They carry an electrical charge, either positive or negative. Compounds are electrically neutral. Therefore in an ionic compound there must be the right number of each sort of ion, so that the total positive charge exactly cancels out the total negative charge. Obviously, then, if you are going to work out a formula, you need to know the charges on the ions.

CASES WHERE YOU CAN WORK OUT THE CHARGE ON AN ION

Any element in Group 2 has 2 outer electrons, which it will lose to form a 2+ ion. Any element in Group 6 has 6 outer electrons, and it has room to gain 2 more; this leads to a 2– ion. Similar arguments apply in the other groups shown in Table 6.1.

Table 6.1 The charges on an ion in Groups 1–7

Group in Periodic Table	Charge on ion	Example
1	1+	Na^+
2	2+	Mg^{2+}
3	3+	Al^{3+}
5	3–	N^{3-}
6	2–	O^{2-}
7	1–	Br^-

HINT

You will always have a copy of the Periodic Table, even in an exam. That means that you can always find out which group an element is in. Elements in Group 4 only form a few ionic compounds and the situation is a bit more complicated. You will need to learn that lead forms a 2+ ion (Pb^{2+}).

REMINDER

Remember that all metals form positive ions.

CASES WHERE THE NAME TELLS YOU THE CHARGE

All metals form positive ions. Names such as lead(II) oxide, iron(III) chloride or copper(II) sulfate tell you directly about the charge on the metal ion. The number after the metal tells you the number of charges, so:

- lead(II) oxide contains a Pb^{2+} ion
- iron(III) chloride contains an Fe^{3+} ion
- copper(II) sulfate contains a Cu^{2+} ion.

You cannot work out the charges for some ions, you have to learn them. Ions that need to be learned are shown in Table 6.2.

Table 6.2 Ions that you should learn.

Charge	Substance	Ion	Charge	Substance	Ion
positive	zinc	Zn^{2+}	negative	nitrate	NO_3^-
	silver	Ag^+		hydroxide	OH^-
	hydrogen	H^+		carbonate	CO_3^{2-}
	ammonium	NH_4^+		sulfate	SO_4^{2-}

You will encounter other ions during the course, but these are the important ones for now. The ions in this list are the difficult ones – be sure to learn both the formula and the charge for each ion.

KEY POINT

Ammonium chloride (NH_4Cl) is an example of an ionic compound that does not contain a metal. There is ionic bonding between the NH_4^+ and Cl^- ions. There is, however, also covalent bonding (see Chapter 7) in this compound: the NH_4^+ ion is held together by covalent bonding.

CONFUSING ENDINGS!

Don't confuse ions such as sulf**ate** and sulf**ide**. A name like copper(II) sulf**ide** means that it contains copper and sulfur **only**. Any '**ide**' ending means that there isn't anything complicated there. Sodium chloride, for example, is just sodium and chlorine combined together. So copper(II) sulfide contains Cu^{2+} and S^{2-} ions.



copper(II) sulfide

▲ Figure 6.11 Copper(II) sulfide is CuS.

HINT

Not looking carefully at word endings is one of the most common mistakes students make when they start to write formulae. Be careful!

Once you have an '**ate**' ending, it means that there is oxygen (and possibly other things) there as well. So, for example, copper(II) sulfate contains copper, sulfur and oxygen.



copper(II) sulfate

▲ Figure 6.12 Copper(II) sulfate is $CuSO_4$.

DEDUCING THE FORMULA FOR AN IONIC COMPOUND

EXAMPLE 1

To find the formula for sodium oxide

Sodium is in Group 1, so the ion is Na^+.

Oxygen is in Group 6, so the ion is O^{2-}.

To have equal numbers of positive and negative charges, you would need two sodium ions to provide the two positive charges to cancel the two negative charges on one oxide ion. In other words, you need:

Na^+ Na^+ O^{2-}

The formula is therefore **Na_2O**.

EXAMPLE 2

To find the formula for barium nitrate

Barium is in Group 2, so the ion is Ba^{2+}.

Nitrate ions are NO_3^-. You will have to remember this.

To have equal numbers of positive and negative charges, you would need two nitrate ions for each barium ion.

The formula is **$Ba(NO_3)_2$**.

Notice the brackets around the nitrate group. *Brackets must be written if you have more than one of these complex ions* (ions containing more than one atom). In any other situation, they are completely unnecessary.

KEY POINT

If you didn't write the brackets, the formula would look like this: $BaNO_{32}$. That would read as 1 barium, 1 nitrogen and 32 oxygens!

EXAMPLE 3

To find the formula for iron(III) sulfate

Iron(III) tells you that the metal ion is Fe^{3+}.

Sulfate ions are SO_4^{2-}.

To have equal numbers of positive and negative charges, you would need two iron(III) ions for every three sulfate ions, giving 6+ and 6– in total.

The formula is $\mathbf{Fe_2(SO_4)_3}$.

A shortcut to working out complicated formulae such as these is to just swap over the numbers in the charges. This is shown in Figure 6.13.



▲ Figure 6.13 If you cross over the numbers in the charges you will get the formula.

CALCIUM CHLORIDE PROVIDES ANOTHER EXAMPLE

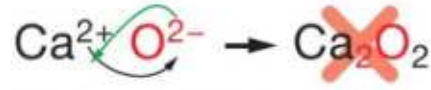


▲ Figure 6.14 To work out the formula of calcium chloride we cross over the numbers in the charges. There is no extra number in front of the charge in Cl^- because we do not tend to write in a 1.

KEY POINT

Why aren't ion charges shown in formulae? Actually, they can be shown. For example, the formula for sodium chloride is NaCl. It is sometimes written Na^+Cl^- if you are trying to make a particular point, but for most purposes the charges are left out. In an ionic compound, the charges are there, whether you write them or not.

You have to be careful using this method because you can get the wrong answer when the charges on the ions are the same. For example, the formula of calcium oxide is CaO and not Ca_2O_2. When the charges on the positive and negative ions are the same you can deduce that there will be 1 of each ion in the formula, so there is no need to swap anything over.



▲ Figure 6.15 The formula of calcium oxide is CaO and not Ca_2O_2.

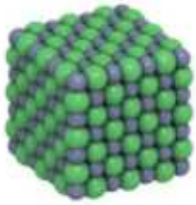
GIANT IONIC STRUCTURES

All ionic compounds form crystals that consist of lattices of positive and negative ions packed together in a regular way. A **lattice** is a regular **array** of particles. The lattice is held together by the strong electrostatic attractions between the positively and negatively charged ions.



▲ Figure 6.16 A lattice fence. A lattice is a regular, repeating structure.

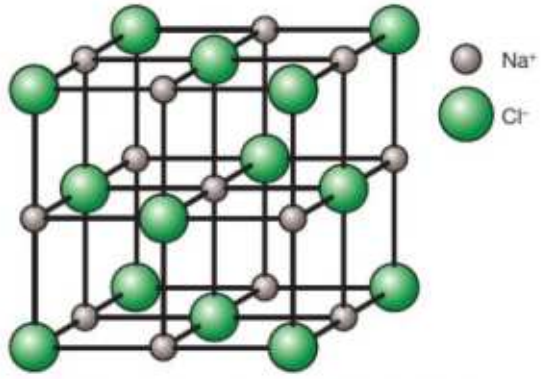
THE STRUCTURE OF SODIUM CHLORIDE



▲ Figure 6.17 A model of a small part of a sodium chloride crystal

Figure 6.17 shows how the ions in a crystal of sodium chloride are arranged.

In diagrams, the ions are usually drawn in an 'exploded' view (Figure 6.18). Each sodium ion is surrounded by 6 chloride ions. In turn, each chloride ion is surrounded by 6 sodium ions. You have to remember that this pattern repeats itself throughout the structure over vast numbers of ions.



▲ Figure 6.18 An 'exploded' view of sodium chloride. The lines in this diagram are not bonds, they are just there to help show the arrangement of the ions. Those ions joined by lines are touching each other.

The structure of sodium chloride is described as a **giant ionic lattice**. We are using the word '**giant**' here not in the sense of big but rather to describe a structure where there are no individual molecules. All the sodium ions in the structure attract all the chloride ions, we cannot pick out sodium chloride molecules; there are no individual molecules. The bonding in a giant ionic lattice extends throughout the structure in all directions. There is no limit to the number of particles present, all we know is that there must be the same number of sodium and chloride ions.

HINT

This is really important: you must not talk about *molecules* of an ionic compound. This will be marked wrong in the exam and you could lose all the marks for a question!

THE STRUCTURE OF MAGNESIUM OXIDE

Magnesium oxide, MgO, contains magnesium ions, Mg^{2+}, and oxide ions, O^{2-}. It has exactly the same structure as sodium chloride. The only difference is that the magnesium oxide lattice is held together by stronger forces of attraction. This is because in magnesium oxide, 2+ ions are attracting 2– ions. In sodium chloride, the electrostatic attractions are weaker because they are only between 1+ and 1– ions.

EXTENSION WORK

The Mg^{2+} ion is also smaller than the Na^+ ion, and the O^{2-} ion is smaller than the Cl^- ion. This causes stronger attractions but the effect of the charge on the ions is more important.



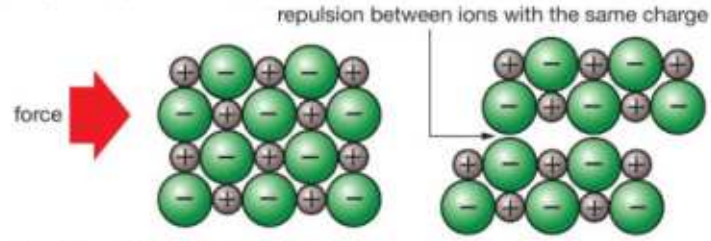
▲ Figure 6.19 Sodium chloride is crystalline

THE PHYSICAL PROPERTIES OF IONIC SUBSTANCES

Ionic compounds have high melting points and boiling points because of the strong electrostatic forces of attraction holding the lattice together. A lot of energy has to be supplied to break the strong electrostatic forces of attraction between oppositely charged ions in the giant lattice structure.

Ionic compounds tend to be crystalline. This reflects the regular arrangement of ions in the lattice. Sometimes the crystals are too small to be seen except under powerful microscopes. Magnesium oxide, for example, is always seen as a white powder because the individual crystals are too small to be seen with the naked eye.

Ionic crystals tend to be brittle. This is because any small distortion of a crystal will bring ions with the same charge alongside each other. Like charges repel and so the crystal splits itself apart.



▲ Figure 6.20 Ionic crystals tend to be brittle

KEY POINT

Organic solvents include ethanol (alcohol) and **hydrocarbons**, such as hexane and those found in petrol. If you are interested in these, you could explore the organic chemistry section of this book (Unit 4).

Ionic substances tend to be soluble in water.

Ionic compounds tend to be insoluble in organic solvents.

EXTENSION WORK

The reasons that ionic compounds tend to be soluble in water are quite complicated. Water is a covalent molecule (Chapter 7) but the electrons in the bonds are more attracted towards the oxygen end of the bond. This makes the oxygen slightly negative and the hydrogen slightly positive – the molecule is called **polar**. This means that reasonably strong forces can be formed between water molecules and ions, which provide the energy to break the lattice apart.

Not all ionic substances are soluble in water: magnesium oxide isn't soluble in water because the attractions between the water molecules and the ions aren't strong enough to overcome the very strong electrostatic forces of attraction between magnesium and oxide ions.

Hexane is non-polar and does not form strong enough attractions to the ions to break apart the ionic lattice.

THE ELECTRICAL CONDUCTIVITY OF IONIC SUBSTANCES

HINT

Molten just means that the salt has been melted – it is a liquid.

Ionic compounds don't conduct electricity when they are solid because the *ions* are fixed in position and are not free to move around. They do, however, conduct electricity when they are **molten** (have melted) or if they are dissolved in water (in aqueous solution). This happens because the *ions* then become free to move around. It is really important that you use the correct words when explaining this. Do not use the word 'electrons'. You must talk about the **ions** being free to move.

CHAPTER QUESTIONS

SKILLS INTERPRETATION

SKILLS CRITICAL THINKING

1 a Explain what is meant by i an ion and ii ionic bonding.

b In each of the following cases, write down the electronic configurations of the original atoms and then explain (in words or diagrams) what happens when:

i sodium bonds with chlorine to make sodium chloride

ii lithium bonds with oxygen to make lithium oxide

iii magnesium bonds with fluorine to make magnesium fluoride.

SKILLS INTERPRETATION

2 Draw dot-and-cross diagrams to show the ions formed (outer electrons only) when:

a potassium combines with fluorine

b calcium combines with bromine

c magnesium combines with iodine.

SKILLS CRITICAL THINKING

3 a State the formula of the ion formed by:

i magnesium
ii strontium
iii potassium
iv oxygen
v sulfur
vi caesium
vii chlorine
viii iodine
ix aluminium
x calcium
xi nitrogen

b State the name of each negative ion in a.

4 Work out the formulae of the following compounds:

lead(II) oxide	sodium bromide
magnesium sulfate	zinc chloride
potassium carbonate	ammonium sulfide
calcium nitrate	iron(III) hydroxide
iron(II) sulfate	copper(II) carbonate
aluminium sulfate	calcium hydroxide
cobalt(II) chloride	calcium oxide
silver nitrate	iron(III) fluoride
ammonium nitrate	rubidium iodide
sodium sulfate	chromium(III) oxide

SKILLS REASONING

5 Explain why sodium chloride:

a has a high melting point

b does not conduct electricity when solid

c conducts electricity when molten.

6 Predict, giving reasons, whether you would expect potassium chloride to have a higher or lower melting point than calcium oxide.

7 COVALENT BONDING

We met ionic compounds in Chapter 6 and in this chapter we will understand what covalent bonding is. There are a lot more covalent compounds than ionic compounds so it is important that you understand how the bonding works.



▲ Figure 7.1 Water is a covalent compound but the salt dissolved in sea water is an ionic compound.

LEARNING OBJECTIVES

- Know that a covalent bond is formed between atoms by the sharing of a pair of electrons
- Understand covalent bonds in terms of electrostatic attractions
- Understand how to use dot-and-cross diagrams to represent covalent bonds in:
  - diatomic molecules, including hydrogen, oxygen, nitrogen, halogens and hydrogen halides
  - inorganic molecules, including water, ammonia and carbon dioxide
  - organic molecules containing up to two carbon atoms, including methane, ethane, ethene and those containing halogen atoms
- Explain why substances with a simple molecular structure are gases or liquids, or solids with low melting and boiling points
- Understand that the term intermolecular forces of attraction can be used to represent all forces between molecules
- Explain why the melting and boiling points of substances with simple molecular structures increase, in general, with increasing relative molecular mass
- Explain why substances with giant covalent structures are solids with high melting and boiling points
- Explain how the structures of diamond, graphite and C_{60} fullerene influence their physical properties, including electrical conductivity and hardness
- Know that covalent compounds do not usually conduct electricity

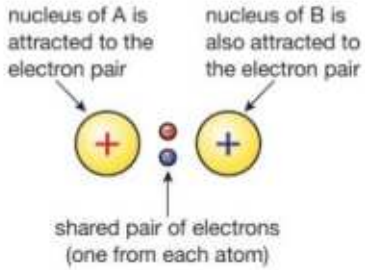
COVALENT BONDING

WHAT IS A COVALENT BOND?

In any bond, particles are held together by electrostatic attractions between something positively charged and something negatively charged. In a **covalent bond**, *a pair of electrons is shared between two atoms.* What holds the atoms together is *the strong electrostatic attraction between the nuclei (positively charged) of the atoms that make up the bond, and the shared pair of electrons (negatively charged).*

EXTENSION WORK

In most of the simple examples you will meet at International GCSE, each atom in a covalent bond supplies one electron to the shared pair of electrons. That doesn't have to be the case. Both electrons may come from the same atom.



▲ Figure 7.2 The shared pair of electrons is attracted to the nuclei of both atoms.

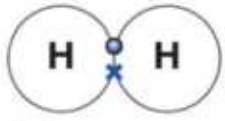
COVALENT BONDING IN A HYDROGEN MOLECULE

HINT

Remember that, although the electrons are drawn as dots or as crosses, there is absolutely no difference between them in reality; the dots and the crosses simply show that the electrons have come from two different atoms.

Covalent bonds are often shown using dot-and-cross diagrams.

Both hydrogen nuclei in Figure 7.3 are strongly attracted to the shared pair of electrons.



▲ Figure 7.3 A dot-and-cross diagram for H_2

Hydrogen atoms form diatomic molecules with the formula H_2. The atoms in an H_2 molecule are joined together by a covalent bond. The covalent bond between two hydrogen atoms is very strong.

Molecules contain a certain fixed number of atoms, which are joined together by covalent bonds. Hydrogen molecules are said to be **diatomic** because they contain two atoms. Other sorts of molecule may have as many as thousands of atoms joined together, for example proteins and DNA.

THE SIGNIFICANCE OF NOBLE GAS STRUCTURES IN COVALENT BONDING

In H_2, each hydrogen atom has only one electron to share, so it can only form one covalent bond. The shared pair of electrons is in the outer shell of both, therefore each atom has the same number of electrons as a noble gas atom (helium in this case).

Does that mean that the hydrogen has turned into helium? No. The number of protons in the nucleus hasn't changed, it is the number of protons that defines what an atom is.

REMINDER

If atoms have 8 electrons in their outer shell they have the same number of electrons as a noble gas atom – they are isoelectronic with a noble gas atom.

In virtually all of the molecules you will meet at this level, electrons will be shared so that H atoms have a total of 2 electrons in their outer shell and all other atoms will have 8 electrons in their outer shell. Some people talk about the '**octet** rule', referring to this 8. Remember, we are counting shared electrons as belonging to the outer shells of both atoms.

When there is one atom in the middle and other atoms are joined to it (as in CH_4 or PCl_3) the *outer* atoms will virtually always have 8 electrons in their outer shell (or 2 if they are H). In fact, it is very difficult to think of an example where the outer atoms do not have 8 electrons. There are some molecules where the *central* atom does not have 8 electrons in the outer shell, and we will look at a couple of examples of those later on.

WHY DOES HYDROGEN FORM MOLECULES?

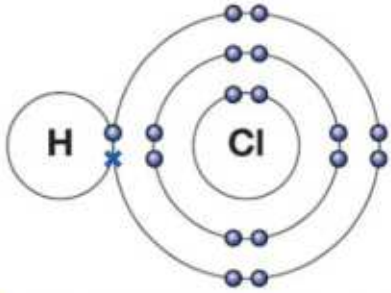
Whenever a bond is formed (of whatever kind), energy is released, and that makes the things involved more stable than they were before. The more bonds an atom can form, the more energy is released and the more stable the system becomes. The H_2 molecule is much more stable than two separate hydrogen atoms.

KEY POINT

In chemistry, we talk about things being more stable or less stable. When we do this we are usually talking about how much energy something has. Generally, the lower the energy something has, the more stable it is. Chemical reactions usually occur so that something becomes more stable. Think about holding a book: if you let go of the book, it will fall to the floor, where it has less (potential) energy, therefore it becomes more stable. When bonds form energy is given out and so the substance formed has less energy, therefore it is more stable.

COVALENT BONDING IN A HYDROGEN CHLORIDE MOLECULE

A chlorine atom has 7 electrons in its outer shell. By sharing 1 electron with a hydrogen atom, both atoms will have the same number of electrons as the nearest noble gas atom. If you look at the arrangement of electrons around the chlorine atom in the covalently bonded molecule of HCl (Figure 7.4), you will see that its electronic configuration is now [2, 8, 8]. That is the same as an argon atom. Similarly, the hydrogen now has 2 electrons in its outer shell – the same as helium.



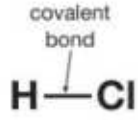
▲ Figure 7.4 A dot-and-cross diagram for HCl.

Notice in Figure 7.4 that only the electrons in the outer shell of the chlorine are used in bonding. In the examples you will meet at International GCSE, the inner electrons never get used. In fact, the inner electrons are often left out of bonding diagrams. But be careful! In an exam, only leave out the inner electrons if the question tells you to. Another way of representing the covalent bonding in HCl is shown in Figure 7.5.



▲ Figure 7.5 The covalent bonding in HCl showing outer shell electrons only.

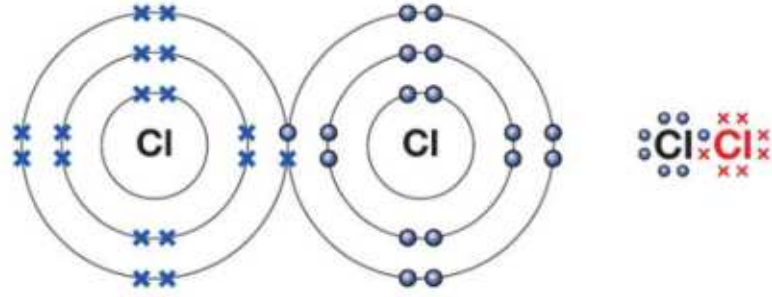
We also use lines to represent the covalent bonds between atoms, but be careful, the diagram shown in Figure 7.6 is not a dot-and-cross diagram.



▲ Figure 7.6 The line between the atoms represents a covalent bond.

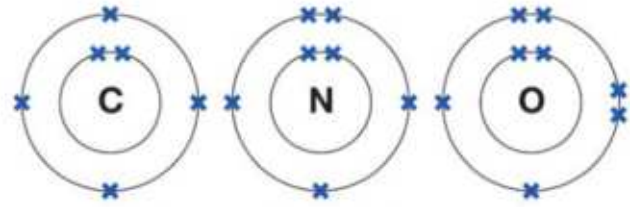
COVALENT BONDING IN A CHLORINE MOLECULE (Cl_2)

A chlorine atom has 7 electrons in its outer shell. Each Cl shares 1 electron so that both Cl atoms will have 8 electrons in their outer shell.



▲ Figure 7.7 Two ways of showing the covalent bonding in Cl_2

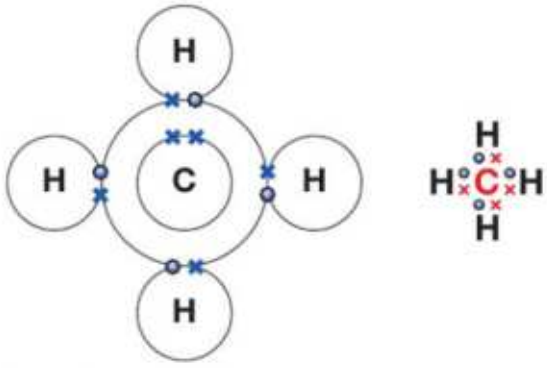
COVALENT BONDING IN METHANE, AMMONIA AND WATER



▲ Figure 7.8 The electronic configurations of C, N and O atoms

COVALENT BONDING IN METHANE

A carbon atom has 4 electrons in its outer shell. By sharing 1 electron with each of 4 hydrogen atoms the C will have 8 electrons in its outer shell and each H will have 2 electrons in its outer shell. Therefore C forms 4 covalent bonds, 1 with each H atom. Methane has the formula CH_4.

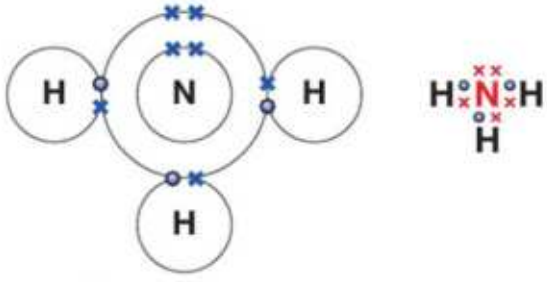


▲ Figure 7.9 Dot-and-cross diagrams for methane

COVALENT BONDING IN AMMONIA

A nitrogen atom has 5 electrons in its outer shell. It will therefore share 3 other electrons to have 8 electrons in its outer shell. In ammonia, a nitrogen atom forms 3 covalent bonds, 1 with each H atom.

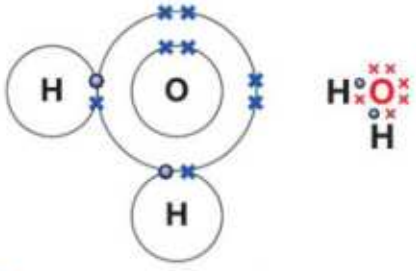
The formula of ammonia is NH_3.



▲ Figure 7.10 Dot-and-cross diagrams for ammonia

COVALENT BONDING IN WATER

An oxygen atom has 6 electrons in its outer shell. It will therefore share 2 other electrons to have 8 electrons in its outer shell. In water, an oxygen atom forms 2 covalent bonds – 1 with each H atom. The formula of water is H_2O.



▲ Figure 7.11 Dot-and-cross diagrams for water

LOOKING AHEAD

Shapes of molecules



▲ Figure 7.12 (a) A methane molecule is tetrahedral and (b) a water molecule is bent.

By understanding the bonding in a covalent molecule it is possible to work out the shape of the molecule. Pairs of electrons in the outer shell of the central atom repel each other and will therefore tend to get as far apart as possible. For example, in a methane molecule there are four pairs of electrons around the central C atom and for these to be as far away from each other as possible, they must be arranged in a tetrahedral shape. A tetrahedron (adjective: tetrahedral) is a triangular pyramid.

There are also four pairs of electrons around the central atom in water: two of these are pairs of electrons involved in covalent bonds and two are pairs of electrons in the outer shell of the oxygen which are not involved in bonding (these are often called *lone pairs of electrons* or just *lone pairs*). These four pairs of electrons are also arranged in a tetrahedral arrangement so the actual shape of a water molecule (how the atoms are arranged) is described as 'bent' or 'V-shaped'. The fact that a water molecule is bent and the electrons are attracted to a different extent by the oxygen and hydrogen atoms means that a water molecule is polar (has a slightly negative and a slightly positive end) and that a stream of water can be bent by an electrically charged object.



▲ Figure 7.13 Water being bent by an electrically charged comb.

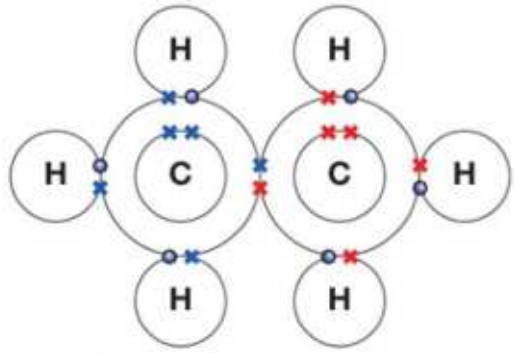
COVALENT BONDING IN A SLIGHTLY MORE COMPLICATED MOLECULE: ETHANE

Ethane has the formula C_2H_6. The bonding is similar to methane (Figure 7.9), except that there is a carbon–carbon covalent bond as well as the carbon–hydrogen bonds.

This is called an organic compound. You will learn more about molecules such as this in Unit 4.

HINT

When drawing molecules containing carbon and hydrogen it is useful to remember that carbon always forms 4 bonds by sharing 4 electrons, and hydrogen always forms 1 bond by sharing 1 electron. The hydrogen atoms always go on the outside, never in the middle.

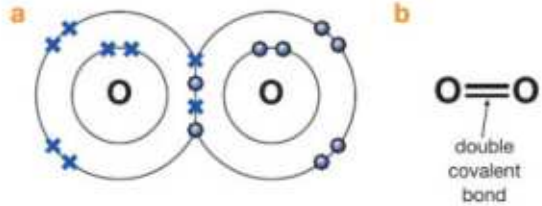


▲ Figure 7.14 A dot-and-cross diagram for ethane

MULTIPLE COVALENT BONDING

COVALENT BONDING IN AN OXYGEN MOLECULE: DOUBLE BONDING

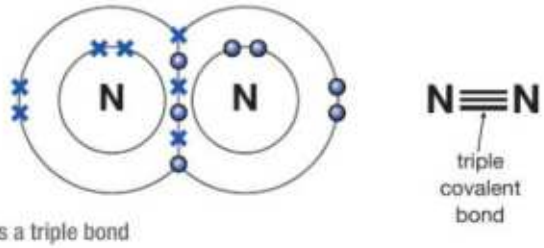
An oxygen atom has 6 electrons in its outer shell and so if two oxygen atoms combine, they will both share 2 electrons each; this means that each atom will have 8 electrons in its outer shell. There are therefore two shared pairs of electrons between the oxygen atoms; this is called a double covalent bond or, usually, just a **double bond**.



▲ Figure 7.15 (a) A dot-and-cross diagram for O_2 and (b) the double covalent bond.

THE TRIPLE BOND IN A NITROGEN MOLECULE

A nitrogen atom has 5 electrons in its outer shell and so if two nitrogen atoms combine they will both share 3 electrons each; this means that each atom will have 8 electrons in its outer shell. There are, therefore, three shared pairs of electrons between the nitrogen atoms; this is called a triple covalent bond or, usually, just a **triple bond**.

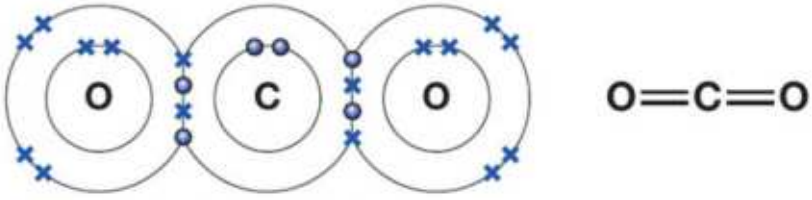


▲ Figure 7.16 N_2 has a triple bond

Nitrogen gas consists of nitrogen molecules bonded like this. The triple bond from the sharing of three pairs of electrons between the two nitrogen atoms is very strong and needs a lot of energy to break. That is why nitrogen is relatively unreactive.

COVALENT DOUBLE BONDING IN CARBON DIOXIDE, CO_2

An oxygen atom has 6 electrons in its outer shell and a carbon atom has 4. Each oxygen atom will share 2 electrons with the carbon atom. Two double bonds are formed between the carbon and the two oxygens (Figure 7.17). All atoms have 8 electrons in their outer shells.



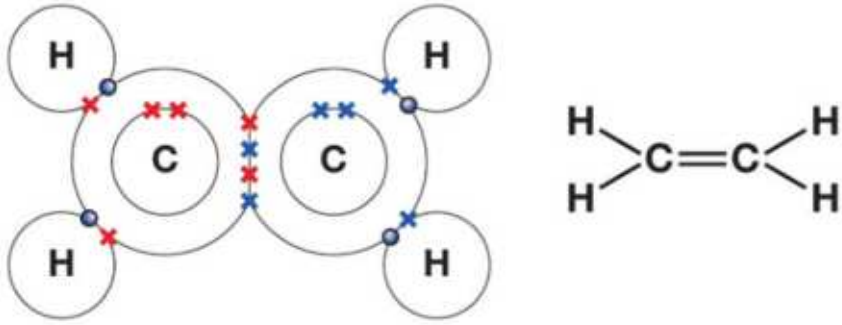
▲ Figure 7.17 CO_2 has two double bonds between atoms.

THE DOUBLE BOND IN ETHENE, C_2H_4

Ethene is rather like ethane in Figure 7.14, except that it only has two hydrogen atoms attached to each carbon atom and a double bond between the carbon atoms.

HINT

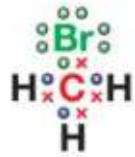
With organic compounds such as ethane and ethene you have to look at their names very carefully, even one different letter in the name can matter. Here, for example, ethane and ethene are completely different compounds. You will find out more about this in Unit 4.



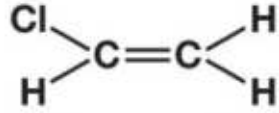
▲ Figure 7.18 Ethene has a double bond between the C atoms.

ORGANIC MOLECULES CONTAINING HALOGEN ATOMS

Bromomethane has the formula CH_3Br: the 3 H atoms and the Br atom are joined to the central C atom. Br has 35 electrons and we have not learned how to work out the electronic configuration of an atom with 35 electrons, but if



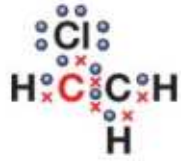
▲ Figure 7.19 A dot-and-cross diagram for CH_3Br showing outer shells only. Although we have used different colours here for clarity, you do not need to use different colours in the exam.



▲ Figure 7.21 The structure of chloroethene showing the covalent bonds. This is not, however, a dot-and-cross diagram and you must not draw this if you are asked to draw a dot-and-cross diagram.

you look at the Periodic Table you will see that Br is in Group 7. Because it is in Group 7 we know that it has 7 electrons in its outer shell, and will share 1 electron so that it has 8 in its outer shell. Therefore, we know that Br will form just 1 covalent bond. When you draw a dot-and-cross diagram for CH_3Br you will only be asked to show the outer electrons (Figure 7.19).

Probably the most complicated molecule for which you could be asked to draw a dot-and-cross diagram would be something like chloroethene (CH_2CHCl). When drawing chloroethene, remember that C will form 4 covalent bonds, H will form 1 and Cl will form 1. The dot-and-cross diagram (outer shells only) is shown in Figure 7.20.



▲ Figure 7.20 There is a double bond between the 2 C atoms. It does not matter where you put the H and Cl atoms relative to the C, and you do not have to use different colours.

The structure of chloroethene can also be shown as illustrated in Figure 7.21.

SOME MORE DIFFICULT MOLECULES WHERE THE CENTRAL ATOM DOES NOT HAVE 8 ELECTRONS IN ITS OUTER SHELL

Although the *outer* atoms in a molecule will always have 8 (or 2 in the case of hydrogen) electrons in their outer shell, there are a few examples you may encounter where the *central* atom has more or fewer than 8 electrons in the outer shell.

BF_3

Boron is the central atom and the Fs are the outer atoms. Each F will share 1 other electron to have 8 electrons in its outer shell. This means that B only has a total of 6 electrons in its outer shell. Another way of thinking about this is that a B atom only has 3 electrons in its outer shell, and so this is the maximum number that it can share.



▲ Figure 7.22 A dot-and-cross diagram for BF_3

SO_2

EXTENSION WORK

Atoms in Periods 3 and below (4, 5, 6, 7) can have more than 8 electrons in their outer shells. The maximum number of electrons that the central atom in a molecule can share is equal to the number of electrons in its outer shell. So, sulfur can form up to 6 bonds (in SF_6) and chlorine 7 (in $HClO_4$).

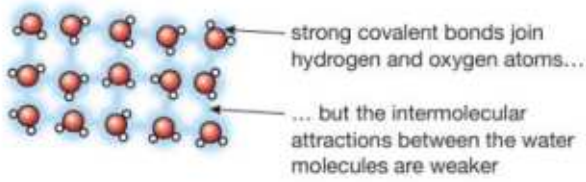
This is called sulfur dioxide or sulfur(IV) oxide. The central atom is S and the outer atoms are O. Each O atom has 6 electrons in its outer shell and so will need to share 2 other electrons to have 8 electrons in the outer shell. So the S atom shares 2 electrons with each of the O atoms to form two double bonds. A sulfur atom originally had 6 electrons in its outer shell and so now, if it shares 4 electrons, it has 10 electrons in its outer shell.



▲ Figure 7.23 There are two double bonds in SO_2.

SIMPLE MOLECULAR STRUCTURES

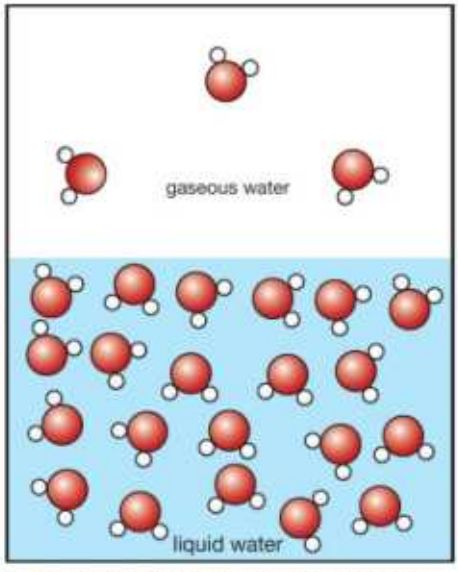
Molecules contain fixed numbers of atoms joined by strong covalent bonds. If we look closely at liquid water, there are individual water molecules, where the H and O atoms are joined together with strong covalent bonds. But there must also be some forces between water molecules which keep them in the liquid state. These forces are **intermolecular forces**.



▲ Figure 7.24 Water is a simple molecular compound.

DID YOU KNOW?

Intermolecular literally means between molecules.



▲ Figure 7.25 Only intermolecular forces are broken when water evaporates/boils.

These intermolecular forces between molecules are much weaker than covalent bonds. When we boil water it is only these weak intermolecular forces of attraction that are broken; covalent bonds are not broken. Looking at Figure 7.25 you can see that there are H_2O molecules in liquid water and in gaseous water. The covalent bonds between the H and O atoms in the molecules have not changed in any way. All that has changed in gaseous water is that there are no intermolecular forces, they have been broken.

When a substance consists of molecules with intermolecular forces of attraction between them, we say that it has a *simple molecular structure*. Examples of things that have simple molecular structures are H_2O, CO_2, CH_4, NH_3 and C_2H_4. These are all the things that we have drawn dot-and-cross diagrams for above. Virtually all the compounds you will encounter that have covalent bonding will have simple molecular structures.

Substances with simple molecular structures tend to be gases or liquids or solids with low melting points and boiling points. The reason for this is that not much energy is required to break the weak intermolecular forces of attractions between molecules. Remember, no covalent bonds are broken, covalent bonds are strong.

EXTENSION WORK

If you continue with chemistry you will learn that there are different types of intermolecular forces. You will come across terms like van der Waals' forces, London dispersion forces and hydrogen bonds. There is a special type of intermolecular force between water molecules called **hydrogen bonds**. Hydrogen bonding gives water some of its very special properties, for example the solid form (ice) is less dense than the liquid form.

MELTING AND BOILING POINTS INCREASE AS RELATIVE MOLECULAR MASS INCREASES

The halogens (Group 7 in the Periodic Table) all have a simple molecular structure consisting of diatomic molecules with intermolecular forces between them.

You can see from Table 7.1 that the melting points and boiling points increase as the relative molecular mass increases.

Table 7.1 The melting points and boiling points of the halogens.

Halogen	Formula	Relative molecular mass / M_r	Melting point / °C	Boiling point / °C
fluorine	F_2	38	−220	−188
chlorine	Cl_2	71	−101	−34
bromine	Br_2	160	−7	59
iodine	I_2	254	114	184

EXTENSION WORK

It is not always the case that melting and boiling points increase as the M_r increases and really the rule only applies to sets of very similar substances, such as the halogens or the alkanes (see Chapter 18). Some examples where the rule does not work are water (M_r = 18, boiling point = 100 °C), ethane (M_r = 30, boiling point = –89 °C), NH_3 (M_r = 17, boiling point = –33 °C) and PH_3 (M_r = 34, boiling point = –88 °C).

Remember, as we melt or boil these substances we are only breaking the intermolecular forces of attraction between molecules. The boiling points increase down this group, which means we have to put in more energy to break the intermolecular forces as the relative molecular mass increases. This means that the *intermolecular forces of attraction must become stronger as relative molecular mass increases*.

This is something that we see quite often in chemistry, for example boiling points increase along the series CH_4, C_2H_6, C_3H_8 as relative molecular mass increases. This is discussed further in Chapter 18.

SOME OTHER PHYSICAL PROPERTIES OF COVALENT COMPOUNDS

KEY POINT

We are using the term covalent molecular compounds to mean covalent compounds with a simple molecular structure.

Covalent molecular compounds do not conduct electricity. This is because the molecules don't have any overall electrical charge (there are no ions) and all the electrons are held tightly in the atoms or in covalent bonds and so are not able to move from molecule to molecule.

Covalent molecular substances tend to be insoluble in water. There are some exceptions to this, for example ethanol (C_2H_5OH) and substances such as NH_3 and HCl that react with water as they dissolve.

Covalent molecular substances are often soluble in organic solvents.

GIANT COVALENT STRUCTURES

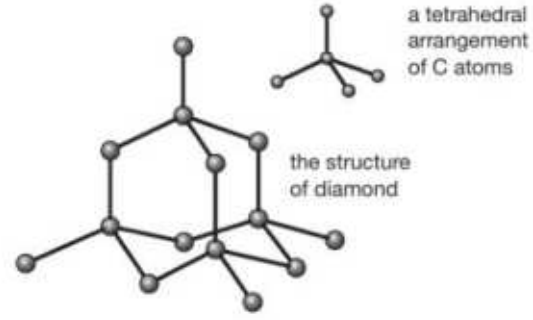
DIAMOND

KEY POINT

A tetrahedron is a triangular-based pyramid. In a tetrahedral arrangement, one atom is at the centre of the tetrahedron, and the atoms it is attached to are at the four corners. Look carefully at the top five atoms in Figure 7.26 to see what this looks like. You will find other similar arrangements in this diagram.
In Figure 7.26 some carbon atoms seem to be forming only two bonds (or even one bond), but that's not really the case. We are only showing a small part of the whole structure. The structure continues in three dimensions, and each of the atoms drawn here is attached to four others. Each of the lines in this diagram represents a covalent bond.

Diamond is a form of pure carbon.

Each carbon atom has four electrons in its outer shell and it therefore forms four covalent bonds. In diamond, each carbon bonds strongly to four other carbon atoms in a *tetrahedral* arrangement. Figure 7.26 shows enough of the structure to see what is happening.



▲ Figure 7.26 Part of the structure of diamond

This is a giant covalent structure; it continues on and on in three dimensions. It is *not* a molecule because the number of atoms joined up in a real diamond is completely variable and depends on the size of the crystal. Molecules always contain *fixed numbers* of atoms joined by covalent bonds.

Diamond has a very high melting and boiling point. This is because of the very strong carbon–carbon covalent bonds, which extend throughout the whole crystal in three dimensions. A lot of energy has to be supplied to break these strong covalent bonds, therefore diamond has very high melting and boiling points. It is important to realise how this is different from the simple molecular structures that we saw above. In order to melt or boil a substance with a simple molecular structure, such as CH_4, we only had to supply enough



▲ Figure 7.27 Diamond (a form of carbon) is crystalline, and is the hardest naturally occurring substance.

energy to break the relatively weak intermolecular forces of attraction. In diamond there are no intermolecular forces (it has a giant structure, there are no molecules). Covalent bonds, which are very strong, must be broken in order to melt or boil it.

In general, *all substances with giant covalent structures are solids with high melting and boiling points* because a lot of energy has to be supplied to break all the strong covalent bonds throughout the giant structure. Other substances with giant covalent structures include graphite (discussed below) and silicon dioxide (SiO_2).

Diamond is very hard. Again, a lot of energy has to be supplied to break the strong covalent bonds in the giant structure. Drill bits can be tipped with diamonds for drills used on stone and rock.

Diamond doesn't conduct electricity. All the electrons in the outer shells of the carbon atoms are tightly held in covalent bonds between the atoms. None are free to move around.

EXTENSION WORK

Diamond doesn't dissolve in water or in any other solvent. This is again because of the strong covalent bonds between the carbon atoms. If the diamond dissolved, these bonds would have to be broken.
Diamond conducts heat very well (better than any other element). As one end of the crystal is heated the atoms vibrate more. The strong bonds throughout the giant structure mean that these vibrations are quickly transmitted from one end of the crystal to the other.

GRAPHITE

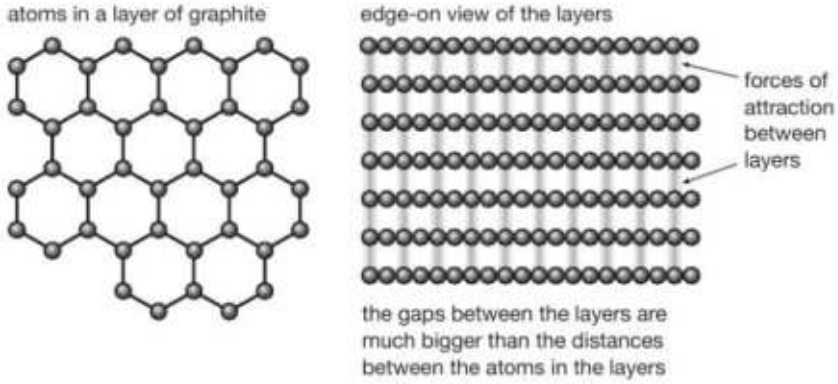
Graphite is also a form of carbon, but the atoms are arranged differently, although it still has a giant structure. Graphite has a *layer structure*, rather like a pack of playing cards. In a pack of cards, each card is strong but the individual cards are easily separated. The same is true in graphite.



▲ Figure 7.28 Graphite has a structure rather like a pack of playing cards.



▲ Figure 7.29 Graphite is soft with a layer structure.



▲ Figure 7.30 The structure of graphite. Some forces of attraction between layers have been shown. These are not bonds and could have been drawn anywhere between the layers.

EXTENSION WORK

Actually, the reason that the layers slide over each other fairly easily is more complicated than this and graphite is not a lubricant in a vacuum. Graphite being a lubricant relies on water molecules sticking to the surface; this does not happen in a vacuum.

Graphite is a soft material. Although the forces holding the atoms together in each layer are very strong, the attractions between the layers are much weaker and not much energy is needed to overcome them. Layers slide over each other and can easily be flaked off.

Graphite (mixed with clay to make it harder) is used in pencils. When you write with a pencil, you are leaving a trail of graphite layers behind on the paper. Pure graphite is so slippery that it is used as a dry lubricant, for example powdered graphite is used to lubricate locks.

Graphite has high melting and boiling points. To melt/boil graphite, you don't just have to separate the layers, you have to break up the whole structure, including the covalent bonds. That needs very large amounts of energy because the covalent bonds are so strong.



▲ Figure 7.31 Three graphite **electrodes** glow red hot after their removal from an electric arc furnace used to produce steel.

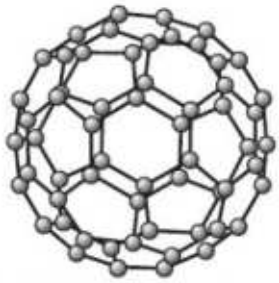
Graphite conducts electricity. If you look back at Figure 7.30, you will see that each carbon atom is joined to only three others. Each carbon atom uses three of its outer shell electrons to form three single covalent bonds. The fourth electron in the outer shell of each atom is free to move around throughout the whole of the layer. The electrons that are free to move throughout the layers are called **delocalised electrons**. The movement of these delocalised electrons allows graphite to conduct electricity.

EXTENSION WORK

Some other properties of graphite are:

- *Graphite is insoluble in all solvents* because it would take too much energy to break all the strong covalent bonds.
- *Graphite is less dense than diamond* because the layers in graphite are relatively far apart. The distance between the graphite layers is more than twice the distance between atoms in each layer. In a sense, a graphite crystal contains a lot of wasted space, which isn't there in a diamond crystal.

C_{60} FULLERENE

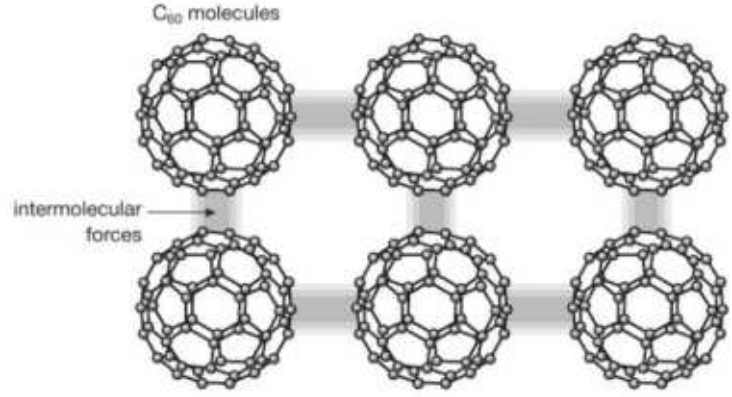


▲ Figure 7.32 A C_{60} fullerene molecule. Remember that molecules consist of fixed number of atoms; each C_{60} fullerene molecule contains 60 carbon atoms joined by covalent bonds.

Diamond and graphite are two **allotropes** of carbon. Allotropes are different forms of the same element. Another allotrope of carbon is C_{60} fullerene. Diamond and graphite both have giant structures but C_{60} fullerene has a simple molecular structure.

In solid or liquid C_{60} fullerene there are C_{60} molecules with weak intermolecular forces between them. The fact that C_{60} has a simple molecular structure has a big influence on its physical properties.

C_{60} fullerene has lower melting and boiling points than diamond and graphite. When fullerene is melted, only the relatively weak intermolecular forces of attraction must be broken. This does not require as much energy as breaking all the strong covalent bonds when diamond and graphite are melted.



▲ Figure 7.33 C_{60} fullerene has a simple molecular structure.

KEY POINT

There are different fullerenes, where the molecules contain different numbers of carbon atoms. This is why we include the C_{60} in the name.

EXTENSION WORK

Unlike diamond and graphite C_{60} fullerene does dissolve in some solvents; only relatively weak intermolecular forces of attraction have to be broken for it to dissolve.

C_{60} fullerene is not as hard as diamond. It does not take as much energy to break the intermolecular forces of attraction in C_{60} fullerene compared to breaking the strong covalent bonds in diamond.

C_{60} fullerene does not conduct electricity. Although all the carbon atoms in C_{60} only form three bonds, the fourth electron on each atom can only move around *within* each C_{60} molecule; the electrons cannot jump from molecule to molecule.

CHAPTER QUESTIONS

You will need to use the Periodic Table in Appendix A on page 708.

SKILLS CRITICAL THINKING

1 State whether each of the following compounds is ionic or covalent:

a MgO b CH_3Br c H_2O_2

d $FeCl_2$ e NaF f HCN

SKILLS INTERPRETATION

2 a What is meant by a covalent bond? How does this bond hold two atoms together?

b Draw dot-and-cross diagrams (showing outer shell electrons only) to show the covalent bonding in

i methane (CH_4)

ii hydrogen sulfide (H_2S)

iii phosphine (PH_3)

iv silicon tetrachloride ($SiCl_4$)

c Draw dot-and-cross diagrams (showing outer shell electrons only) to show the covalent bonding in

i O_2

ii N_2

3 Draw dot-and-cross diagrams (showing outer shell electrons only) to show the covalent bonding in

a ethane (C_2H_6) b ethene (C_2H_4) c chloroethane (CH_3CH_2Cl)

SKILLS REASONING

4 Explain why carbon dioxide sublimes at –78.5 °C but diamond sublimes at around 4000 °C.

5 Hexane has the formula C_6H_{14}. It is a liquid at room temperature.

a Explain whether hexane has a simple molecular or giant structure.

b Explain whether you would expect pentane (C_5H_{12}) to have a higher or lower boiling point than hexane.

c Explain whether or not you would expect hexane to conduct electricity.

6 Explain the following in terms of structure and bonding:

a diamond is harder than graphite

b C_{60} fullerene has a lower melting point than graphite

c graphite conducts electricity

d diamond does not conduct electricity.

SKILLS ANALYSIS

7 The table below gives details of the boiling temperatures of some substances made of covalent molecules. Arrange these substances in increasing order of the strength of their intermolecular forces and explain your order.

Substance	Boiling point / °C
ammonia	–33
ethanamide	221
ethanol	78.5
hydrogen	–253
phosphorus trifluoride	–101
water	100

(Don't panic if you don't recognise some of the names. The substances could also have been labelled A, B, C, D, E and F.)

SKILLS REASONING

8 The compound N_2F_2 has the structure:



a Explain whether you would expect the bond between the nitrogen atoms to be a single, double or triple bond.

SKILLS INTERPRETATION

b Draw a dot-and-cross diagram for N_2F_2 showing outer electrons only.

SKILLS REASONING

9 a Draw a dot-and-cross diagram (showing outer electrons only) to show the covalent bonding in BCl_3.

b BCl_3 is sometimes described as an *electron-deficient* compound. Explain what you think that means.

UNIT QUESTIONS

You may need to refer to the Periodic Table on page 708.

SKILLS CRITICAL THINKING

1

Hydrogen is the most common element in the universe.

The melting point and boiling point of hydrogen are shown in the table:

Melting point / °C	–259
Boiling point / °C	–253

a Put a cross in the box to show a temperature at which hydrogen is a liquid. **(1)**

–265 °C ☐ –260 °C ☐ –255 °C ☐ –250 °C ☐

SKILLS INTERPRETATION

b The circle in the diagram represents 1 molecule of hydrogen. Complete the diagram to show the arrangement of particles in liquid hydrogen. You should add at least 10 more circles to the diagram. **(2)**



SKILLS PROBLEM SOLVING

c Hydrogen has three isotopes, the least common of which is tritium, ^{3}H. Use the Periodic Table to work out the number of protons, neutrons and electrons in an atom of tritium. **(3)**

Number of protons:

Number of neutrons:

Number of electrons:

d Hydrogen reacts with nitrogen to form ammonia (NH_3).

i The electronic configuration of a nitrogen atom is (put a cross in one box): **(1)**

2, 2, 3 ☐ 2, 5 ☐ 2, 8, 4 ☐ 2, 2, 8, 2 ☐

SKILLS CRITICAL THINKING

ii Draw a dot-and-cross diagram, showing outer electrons only, to show the bonding in an ammonia molecule. **(2)**

e Ammonia forms salts that contain the ammonium ion. Put a cross in the box to show which of the following formulae for ammonium compounds is incorrect.

NH_4SO_4 ☐ NH_4NO_3 ☐ NH_4Cl ☐ $(NH_4)_2CO_3$ ☐

SKILLS CRITICAL THINKING

f Two more compounds that contain hydrogen are water and ethanol. Put a cross in the box to show a method that can be used to separate a mixture of ethanol and water. **(1)**

crystallisation	☐	simple distillation	☐
filtration	☐	fractional distillation	☐

(Total 10 marks)

2

a Complete the following passage by using the words below. You may use the words once, more than once, or not at all. **(4)**

mass number	atomic number	groups	periods
protons	electrons	outer shell	nucleus

The elements in the Periodic Table are arranged in order of _____.

The vertical columns are called _____ and contain elements which have the same number of _____ in their _____.

b Put a cross next to the symbol(s) of elements that are non-metals. **(2)**

H ☐ V ☐ Pb ☐ Ar ☐ W ☐

SKILLS REASONING

c Silicon is an element that shows some of the properties of metals and non-metals. It is sometimes called a *metalloid*.

i Two properties of silicon are:

- silicon conducts electricity
- silicon forms an oxide (SiO_2) that reacts with hot concentrated sodium hydroxide.

Explain which of these is not a property of metals. **(2)**

SKILLS ANALYSIS, REASONING

ii The structure of silicon dioxide (SiO_2) is shown in the diagram. This structure continues in all directions.



Explain in terms of electronic configurations and bonding whether the grey or red circles in this diagram represent silicon atoms. **(3)**

iii By referring to the diagram in part ii explain whether you would expect SiO_2 to be a solid, liquid or gas at room temperature. **(2)**

(Total 13 marks)

SKILLS INTERPRETATION, REASONING

3 Strontium is an element in Group 2 of the Periodic Table and bromine is an element in Group 7.

a Explain what happens in terms of electrons when an atom of strontium combines with an atom of bromine to form strontium bromide. You may draw a diagram to illustrate your answer. **(3)**

b Explain in terms of structure and bonding whether you would expect strontium bromide to have a high or a low melting point. **(3)**

c Explain what you understand by the term 'relative atomic mass' of an element. **(2)**

SKILLS PROBLEM SOLVING

d The natural abundances of the two isotopes of bromine are:

^{79}Br 50.69%

^{81}Br 49.31%

Calculate the relative atomic mass of bromine. Give your answer to 2 decimal places. **(2)**

SKILLS CRITICAL THINKING

e The formula of strontium nitrate is (put a cross in one box): **(1)**

$SrNO_3$ ☐ $Sr(NO_3)_2$ ☐ $SrNO_{32}$ ☐ Sr_3N_2 ☐

(Total 11 marks)

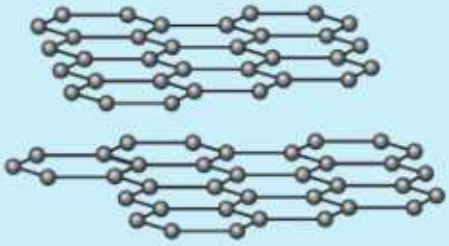
SKILLS REASONING

4 The diagram represents the structure of diamond, a form of carbon.

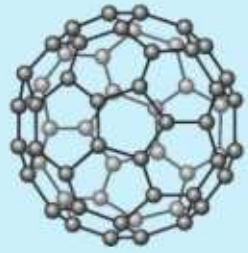


a Explain in terms of structure and bonding why diamond is very hard. **(2)**

b Two more forms of carbon are graphite and C_{60} fullerene. Part of the structure of graphite and a molecule of C_{60} fullerene are shown in the diagram.



graphite



C_{60} fullerene

i Explain whether graphite or C_{60} fullerene has the higher boiling point. **(4)**

ii Explain why graphite conducts electricity. **(2)**

iii Explain why C_{60} fullerene does not conduct electricity. **(2)**

(Total 10 marks)

SKILLS ANALYSIS 7th **5**

a Oxygen gas has the formula O_2. Which of the following is a correct dot-and-cross diagram showing the bonding in O_2 (outer shells of electrons only are shown). Circle one of the diagrams. **(1)**



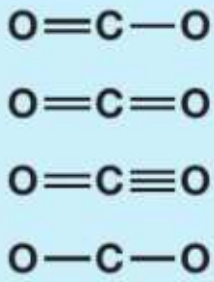
SKILLS CRITICAL THINKING 6th

b Oxygen reacts with potassium to form potassium oxide. Put a cross in one box to indicate what the formula of potassium oxide is. **(1)**

PO ☐ KO ☐ K_2O ☐ KO_2 ☐

SKILLS ANALYSIS

c Oxygen reacts with carbon to form carbon dioxide. Which diagram shows the covalent bonds in carbon dioxide? Circle one diagram. **(1)**



(Total 3 marks)

SKILLS PROBLEM SOLVING 7th **6**

In an experiment to find the empirical formula of lead oxide, a small porcelain dish was weighed, filled with lead oxide and weighed again. The dish was placed in a tube and heated in a stream of hydrogen. The hydrogen reduced the lead oxide to a bead of metallic lead. When the apparatus was cool, the dish and its bead of lead were weighed together.

Mass of porcelain dish = 17.95 g

Mass of porcelain dish + lead oxide = 24.80 g

Mass of porcelain dish + lead = 24.16 g

(A_r: O = 16, Pb = 207)

a Calculate the mass of lead in the lead oxide. **(1)**

b Calculate the mass of oxygen in the lead oxide. **(1)**

9th

c There are three different oxides of lead: PbO, PbO_2 and Pb_3O_4. Use your results from a and b to find the empirical formula of the oxide used in the experiment. **(3)**

(Total 5 marks)

SKILLS PROBLEM SOLVING 7th

7 Copper reacts with concentrated nitric acid to produce copper(II) nitrate solution and nitrogen dioxide gas.

$$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$

A student carried out an experiment to make some copper(II) nitrate crystals.

a The student started with 2.00 g of copper and added excess nitric acid. Calculate the maximum mass of copper(II) nitrate, $Cu(NO_3)_2$, which could be obtained. (A_r: N = 14, O = 16, Cu = 63.5) **(3)**

SKILLS EXECUTIVE FUNCTION 5th

b Explain the method the student could use to obtain crystals of copper(II) nitrate from the copper nitrate solution. **(3)**

SKILLS PROBLEM SOLVING 7th

c The copper nitrate crystallises out of the solution as $Cu(NO_3)_2 \cdot 3H_2O$. The student did some calculations and worked out that he should make 7.61 g of crystals. He actually only made 5.23 g. Calculate the percentage yield of the student's experiment. **(2)**

(Total 8 marks)

THE ALKALI METALS 345 | THE HALOGENS 352 | GASES IN THE ATMOSPHERE 358 | REACTIVITY SERIES 366
ACIDS AND ALKALIS 381 | ACIDS, BASES AND SALT PREPARATIONS 386 | CHEMICAL TESTS 398

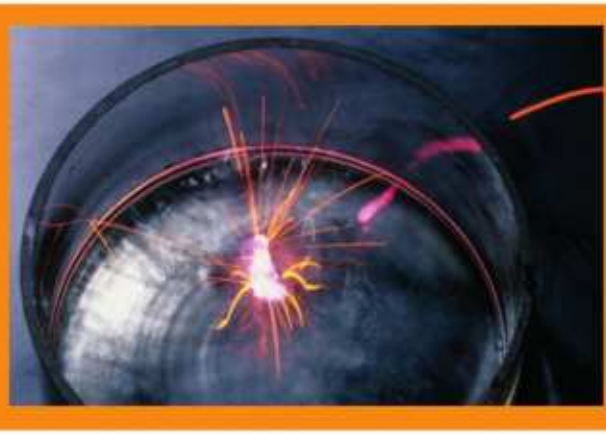
CHEMISTRY UNIT 2 INORGANIC CHEMISTRY

Inorganic chemistry is the study of all the elements in the Periodic Table and the compounds they form, except organic compounds formed by carbon. The properties of these elements are very different and they form a huge variety of compounds. The Periodic Table is the great unifying principle used by inorganic chemists as a guide to understanding the behaviour of the elements and their compounds. Most of the elements in the Periodic Table are metals and these are some of the most important materials that we use in everyday life. However, scientists are always searching for new materials with exciting properties. Inorganic chemists are involved in the development of these new materials, for instance high-temperature superconductors that are used in trains that levitate above the tracks.



8 THE ALKALI METALS

We have already looked at the Periodic Table in Chapter 4. Here we will look at the properties of the elements in Group 1 of the Periodic Table: the alkali metals.



▶ Figure 8.1 Potassium reacting with water. The alkali metals are all reactive metals that react vigorously with water.

LEARNING OBJECTIVES

- Understand how the similarities in the reactions of these elements with water provide evidence for their recognition as a family of elements
- Understand how the differences between the reactions of these elements with air and water provide evidence for the trend in reactivity in Group 1
- Use knowledge of trends in Group 1 to predict the properties of other alkali metals

Li	lithium
Na	sodium
K	potassium
Rb	rubidium
Cs	caesium
Fr	francium

▲ Figure 8.2 The alkali metals

The elements in Group 1 of the Periodic Table are called the **alkali metals**. The group contains the elements shown in Figure 8.2.

Francium (pronounced france-ee-um), at the bottom of the group, is **radioactive**. One of its isotopes is produced during the radioactive decay of uranium-235, but is extremely short-lived. At any one time scientists estimate that there is only about 20–30 g of francium present in the whole of the Earth's crust and no one has ever seen a piece of francium. When you know about the rest of Group 1 you can predict what francium would be like. We will make those predictions later.

PHYSICAL PROPERTIES

	Melting point / °C	Boiling point / °C	Density / g / cm^3
Li	181	1342	0.53
Na	98	883	0.97
K	63	760	0.86
Rb	39	686	1.53
Cs	29	669	1.88

EXTENSION WORK

The reason that the melting points decrease is that the atoms get bigger as we go down the group. In the metallic lattice, the nuclei of the positive ions are further from the delocalised electrons in caesium than in sodium and therefore there is weaker electrostatic attraction.

The melting and boiling points of the elements are very low for metals, and get lower as you move down the group.

Their densities tend to increase down the group, although not regularly. Lithium, sodium and potassium are all less dense than water, and so will float on it.

The metals are also very soft and are easily cut with a knife, becoming softer as you move down the group. They are shiny and silver when freshly cut, but **tarnish** very quickly on exposure to air.

STORAGE AND HANDLING



▲ Figure 8.3 Lithium, sodium and potassium have to be kept in oil to stop them reacting with oxygen in the air.

All these metals are extremely reactive and get more reactive as you go down the group. They all react quickly with oxygen in the air to form oxides, and react rapidly with water to form strongly alkaline solutions of the metal hydroxides. This is why the Group 1 metals are commonly known as the alkali metals.

To stop them reacting with oxygen or water vapour in the air, lithium, sodium and potassium are stored under oil. Rubidium and caesium are so reactive that they have to be stored in sealed glass tubes to stop any possibility of oxygen getting at them.

Great care must be taken not to touch any of these metals with bare fingers. There could be enough sweat on your skin to give a reaction, producing lots of heat and a very **corrosive** metal hydroxide.

A FAMILY OF ELEMENTS

DID YOU KNOW?

Historically alkali metals were put in the same group because of similarities in properties, before anyone knew anything about electrons!

There are two reasons that we put these elements in Group 1:

1 They all have *one* electron in their outer shell. The electronic configurations are:

lithium	2, 1
sodium	2, 8, 1
potassium	2, 8, 8, 1

2 They have similar chemical properties, for example:

- they all react with water (this will be discussed below) in the same way to form a hydroxide with the formula MOH (e.g. LiOH, NaOH) and hydrogen
- they react with oxygen to form an oxide with the formula M_2O (Na_2O, K_2O)
- they react with halogens to form compounds with the formula MX (e.g. LiCl, KBr)
- they form ionic compounds which contain an M^+ ion (e.g. Na^+, K^+).

KEY POINT

'M' simply represents any one of the alkali metals. 'X' represents any one of the halogens.

The chemical properties depend on the number of electrons in the outer shell. The Group 1 elements react in very similar ways because they all have the same number of electrons in the outer shell (one), so reason 2 is really just a consequence of reason 1.

We will discuss the chemical properties in more detail below.

REACTIONS WITH WATER

All these metals react in the same way with water to produce a metal hydroxide and hydrogen:

alkali metal + water → alkali metal hydroxide + hydrogen

$$2M + 2H_2O \rightarrow 2MOH + H_2$$

The main difference between the reactions is how quickly they happen.

As you go down the group, the metals become more reactive and the reactions occur more rapidly.

The reaction between sodium and water is typical.

REMINDER

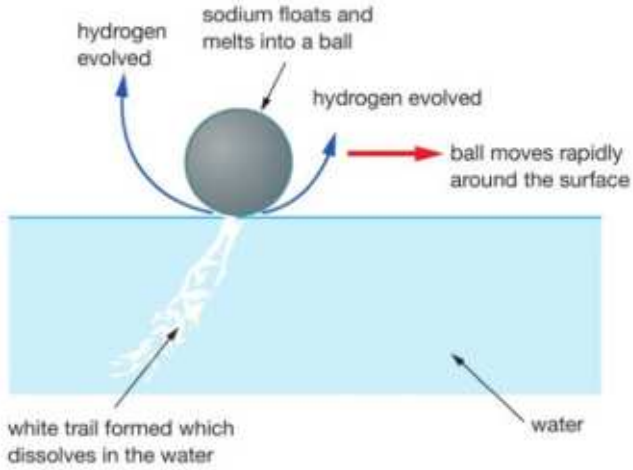
You might need to remind yourself why the formula is MOH by looking at Chapter 6. The charge on the hydroxide ion is 1–.

WITH SODIUM

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

HINT

Strictly speaking, most of the time the sodium is reacting it is present as molten sodium, not solid sodium. Writing (l) for the state symbol has the potential to confuse an examiner and is probably best avoided!



▲ Figure 8.4 Sodium reacting with water. The white trail is the sodium hydroxide, which dissolves in water to form a strongly alkaline solution.

The main observations you can make when this reaction occurs are:

- The sodium floats because it is less dense than water.
- The sodium melts into a ball because its melting point is low and a lot of heat is produced by the reaction.
- There is **fizzing** because hydrogen gas is produced.
- The sodium moves around on the surface of the water. Because the hydrogen isn't given off symmetrically around the ball, the sodium is pushed around the surface of the water, like a hovercraft.
- The piece of sodium gets smaller and eventually disappears. The sodium is used up in the reaction.
- If you test the solution that is formed with universal indicator solution, you will see that the universal indicator goes blue, indicating an alkaline solution has been formed. The metal hydroxide is alkaline (the solution contains the OH^- ion).

HINT

When asked to write *observations* in the exam it is better to write 'fizzing/bubbling/effervescing' rather than 'a gas is given off' because the fizzing/bubbling/effervescing is what you actually see.



▲ Figure 8.5 A hovercraft

HINT

When you are asked about this in the exam, you are often asked to compare the reactions of sodium and lithium so you should explain how you can see that the reaction of lithium is slower. So, for example, you can say that it fizzes more slowly, or the lithium moves around more slowly, or takes longer to disappear.

HINT

Again, if you are asked to compare potassium with sodium use phrases such as:
'fizzes *more* vigorously'
'moves around *more* quickly'
'disappears *more* quickly'
The key difference though is that with potassium the hydrogen bursts into flames but with sodium it usually does not.

Safety note: The reactions of rubidium and caesium would be too hazardous to attempt in school as they would explode.



▲ Figure 8.6 A piece of sodium. The left-hand edge has been freshly cut, so it is shiny.

REMINDER

Remember the charge on the oxide ion is O^{2-} and the charge on an alkali metal ion is M^{+}.

LITHIUM

$$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$$

The reaction is very similar to sodium's reaction, except that it is slower. Lithium's melting point is higher and the heat isn't produced so quickly, so the lithium doesn't melt.

POTASSIUM

$$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$$

Potassium's reaction is faster than sodium's. Enough heat is produced to ignite the hydrogen, which burns with a lilac flame. The reaction often ends with the potassium **spitting** around and exploding.

RUBIDIUM AND CAESIUM

These react even more violently than potassium, and the reaction can be explosive. Rubidium hydroxide and caesium hydroxide are formed.

REACTIONS OF THE ALKALI METALS WITH THE AIR

Lithium, sodium and potassium are all stored in oil because they react with the air. If we look at a piece of sodium which has been taken out of the oil, it usually has a crust on the outside. It is not shiny unless it has been freshly cut.

When the piece of sodium is cut, the fresh surface is shiny but it tarnishes rapidly as the freshly exposed sodium reacts with oxygen in the air. If we do the same with a piece of lithium it tarnishes more slowly because lithium reacts more slowly than sodium. A freshly cut piece of potassium tarnishes extremely rapidly, more quickly than sodium. In this way we can see again that potassium is more reactive than sodium, which is more reactive than lithium. In each case the metal reacts with oxygen in the air to form an oxide with the formula M_2O.

If we heat each of the metals in the air using a Bunsen burner, we get a much more vigorous reaction and it is more difficult to see which metal is most reactive because all the reactions are so rapid.

Lithium burns with a red flame to form lithium oxide.

Sodium burns with a yellow flame to form sodium oxide.

Potassium burns with a lilac flame to form potassium oxide.

The equation for all these reactions is:

$$4M(s) + O_2(g) \rightarrow 2M_2O(s)$$

In each case the product formed is a white powder – the alkali metal oxide.

EXTENSION WORK

When the alkali metals react with air, other types of oxide can also be formed, called peroxides (M_2O_2) and superoxides (MO_2). These all still contain the M^{+} ion, it is the oxygen bit which is different. Lithium can also form a nitride (Li_3N).

COMPOUNDS OF THE ALKALI METALS

All Group 1 metal ions are colourless. That means that their compounds will be colourless or white unless they are combined with a coloured negative ion. Potassium dichromate(VI) is orange, for example, because the dichromate(VI) ion is orange, and potassium manganate(VII) is purple because the manganate(VII) ion is purple. Group 1 compounds are typical ionic solids and are mostly soluble in water.

SUMMARISING THE MAIN FEATURES OF THE GROUP 1 ELEMENTS

Group 1 elements:

- are metals
- are soft with melting points and densities which are very low for metals
- have to be stored out of contact with air or water
- react rapidly with air to form coatings of the metal oxide
- react with water to produce an alkaline solution of the metal hydroxide and hydrogen gas
- increase in reactivity as you go down the group
- form compounds in which the metal has a 1+ ion
- have mainly white/colourless compounds which dissolve to produce colourless solutions.

PREDICTING THE PROPERTIES OF FRANCIUM

As we move down a group in the Periodic Table the properties of the elements change gradually. So, if we know the properties of most of the elements in a group, we should be able to predict the properties of elements we don't know. Francium is extremely radioactive and at any time, anywhere in the world, there is only a tiny amount present; nobody has actually seen a piece of francium. We can, however, predict the properties of francium using the properties of the other alkali metals.

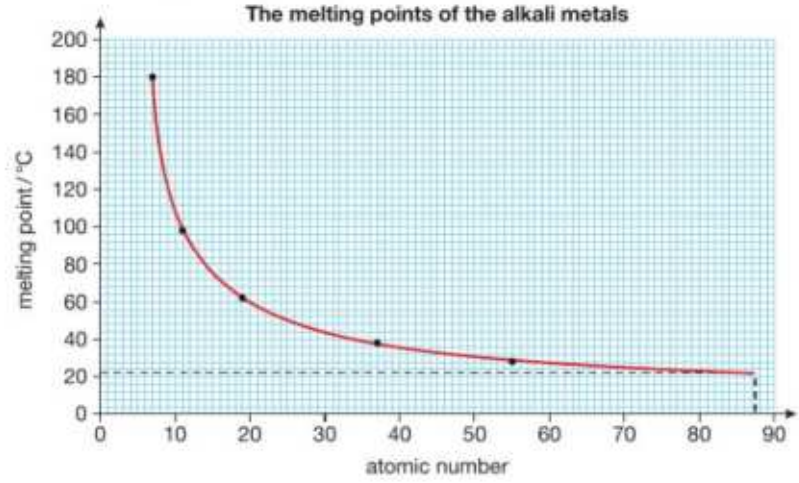
We can predict that francium:

- is very soft
- will have a melting point around room temperature
- has density which is probably just over 2 g/cm^3
- will be a silvery metal, but will tarnish almost instantly in air
- will react violently with water to give francium hydroxide and hydrogen
- will be more reactive than caesium
- will have a hydroxide, francium hydroxide, with the formula FrOH, which will be soluble in water and form a strongly alkaline solution
- will form compounds that are white/colourless and dissolve in water to give colourless solutions.

REMINDER

Remember, you can't actually observe any of these things.

We could use a graphical method to predict the melting point of francium. If we **plot** the melting point of the alkali metals against atomic number then draw a line of best fit we get:



▲ Figure 8.7 This graph allows us to predict the melting point of francium.

If we carry on the line to atomic number 87 we can predict a melting point of about 22 °C.

KEY POINT

Various other predictions give a melting point for francium between 21 °C and 27 °C.

CHAPTER QUESTIONS

SKILLS REASONING

1 Explain why lithium, sodium and potassium are put in the same group in the Periodic Table.

SKILLS CRITICAL THINKING

2 This question concerns the chemistry of the elements Li, Na, K, Rb and Cs. In a and b, you should name the substances represented by letters.

a **A** is the least dense of all the metals.

b When metal **B** is dropped onto water it melts into a small ball and moves rapidly around the surface. A gas, **C**, is given off and this burns with a lilac flame. A solution of **D** is formed.

c Write an equation for the reaction of **B** with water.

SKILLS REASONING

d What would you expect to see if solution **D** was tested with universal indicator paper?

e Explain why **B** melts into a small ball when it is dropped onto water.

SKILLS CRITICAL THINKING

f **E** burns in air with a yellow flame to form compound **F**. Write a word equation and balanced symbol equation for the reaction that occurs.

3 Explain whether each of the following statements is true or false.

a Sodium forms mostly covalent compounds.

b A rubidium atom is larger than a potassium atom.

c All the alkali metals react with air to form oxides.

d Lithium reacts with chlorine to form lithium chloride, which has the formula Li_2Cl.

SKILLS REASONING

4 Imagine that a new alkali metal has recently been discovered and that it fits into the Periodic Table below francium. We will call this new element edexcelium.

a Explain whether you would expect edexcelium to be more or less dense than francium.

SKILLS PROBLEM SOLVING

b State how many electrons edexcelium will have in its outer shell.

SKILLS CRITICAL THINKING

c State the names of the products that will be formed when edexcelium reacts with water.

d Explain whether edexcelium will be more or less reactive than francium.

SKILLS PROBLEM SOLVING

e If the symbol for edexcelium is Ed, write a balanced chemical equation for the reaction of edexcelium with water.

SKILLS CRITICAL THINKING

f When edexcelium reacts with water, will the solution formed be acidic, alkaline or neutral?

SKILLS PROBLEM SOLVING

g Write the formula for the compound formed when edexcelium reacts with air.

9 THE HALOGENS

The elements in Group 7 of the Periodic Table are called the halogens. In this chapter we will look at some of the properties of these elements. When we first look at them, it is hard to see that they form a family of elements because they look so different, but they react in very similar ways.



▶ Figure 9.1 Chlorine, bromine and iodine are three of the halogens.

LEARNING OBJECTIVES

- Know the colours, physical states (at room temperature) and trends in physical properties of the halogens
- Use knowledge of trends in Group 7 to predict the properties of other halogens
- Understand how displacement reactions involving halogens and halides provide evidence for the trend in reactivity in Group 7

F	fluorine
Cl	chlorine
Br	bromine
I	iodine
At	astatine

▲ Figure 9.2 The halogens



▲ Figure 9.3 Iodine is a grey solid but has a purple vapour.

THE HALOGENS

The atoms of fluorine, chlorine, bromine, iodine and astatine all have 7 electrons in their outer shell, therefore these elements are put in Group 7 in the Periodic Table. The number of electrons in the outer shell of an atom determines how something reacts, so all the elements in Group 7 react in a similar way.

The name '**halogen**' means 'salt-producing'. When they react with metals, these elements produce a wide range of salts, including calcium fluoride, sodium chloride, silver bromide and potassium iodide. All the salts contain the X^- ion (where X stands for any halogen atom).

The halogens are non-metallic elements with diatomic molecules: F_2, Cl_2, etc.

Table 9.1 The melting and boiling points of the halogens increase and the colour becomes darker down the group

	Physical state at room temperature	Colour
F_2	gas	yellow
Cl_2	gas	green
Br_2	liquid	red-brown liquid, orange/brown vapour
I_2	solid	grey solid, purple vapour

REMINDER

Remember that intermolecular forces are the forces of attraction between molecules.

The melting and boiling points increase down the group. The halogens are all covalent molecular substances and the melting and boiling points increase as the relative molecular mass increases. As the relative molecular mass increases, the intermolecular forces of attraction become stronger and therefore more energy must be put in to overcome these stronger forces of attraction. Remember, no covalent bonds are broken when these melt/boil.

Because the halogens are non-metals, they are poor conductors of heat and electricity.

Astatine is radioactive and is formed during the radioactive decay of other elements, such as uranium and thorium. Most of its isotopes are so unstable that their lives can be measured in seconds or fractions of a second.

SAFETY

Fluorine is so dangerously reactive that you would never expect to find it in a school lab. Apart from any safety problems, due to the reactivity of the elements (especially fluorine and chlorine), all the halogens have extremely poisonous **vapours** and have to be handled in a **fume** cupboard. Liquid bromine is also very corrosive, and great care has to be taken to keep it off the skin.

REACTIONS OF THE HALOGENS

The halogens react with hydrogen to form **hydrogen halides**: hydrogen fluoride, hydrogen chloride, hydrogen bromide and hydrogen iodide. For example:

$$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$$

KEY POINT

This is something that can be confusing. Hydrogen chloride is a gas and when it dissolves in water it becomes hydrochloric acid. Hydrogen chloride is a gas consisting of HCl molecules and hydrochloric acid is a solution containing H^+ and Cl^- ions. The acids formed by other hydrogen halides are:

HF(aq) hydrofluoric acid
HBr(aq) hydrobromic acid
HI(aq) hydroiodic acid

The hydrogen halides are all acidic, poisonous gases. In common with all the compounds formed between the halogens and non-metals, the gases are covalently bonded. They are very soluble in water, reacting with it to produce solutions of acids. For example, hydrochloric acid is a solution of hydrogen chloride in water:

$$HCl(g) \xrightarrow{\text{dissolve in water}} HCl(aq)$$

hydrogen chloride hydrochloric acid

The halogens react with alkali metals to form salts. For instance, sodium burns in chlorine with its typical yellow flame to produce white, solid sodium chloride:

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

Sodium chloride is an ionic solid. Typically, when the halogens react with metals from Groups 1 and 2, they form ions.



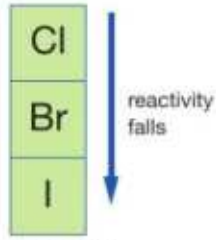
▲ Figure 9.4 Sodium burning in chlorine to produce sodium chloride.

DISPLACEMENT REACTIONS INVOLVING THE HALOGENS

In this section we will look at what happens when we react a solution of a halogen with a solution containing halide ions. These are called **displacement reactions** – you will see why below. We can use these displacement reactions to show that chlorine is more reactive than bromine, which is more reactive than iodine.

KEY POINT

We will concentrate on the three commonly used halogens, but the trend continues for the rest of the group.



▲ Figure 9.5 Reactivity decreases down the group.

REACTING CHLORINE WITH POTASSIUM BROMIDE OR POTASSIUM IODIDE SOLUTIONS

KEY POINT

Although pure liquid bromine is red-brown, in solution it is orange. If the solution is very dilute it may even look yellow.

HINT

You have to be careful with the words you use here. In the exam you must write 'chlorine displaces bromine' not 'chlorine displaces bromide'.

If you add chlorine solution ('chlorine water') to colourless potassium bromide solution, the solution becomes orange as bromine is formed:

$$2KBr(aq) + Cl_2(aq) \rightarrow 2KCl(aq) + Br_2(aq)$$

potassium bromide + chlorine → potassium chloride + bromine

Chlorine is more reactive than bromine and has displaced the bromine from solution. You can think about this in the following way: if something is more reactive, it has a greater tendency to *react* to form a compound. Something that is less reactive is more likely to go back to being the element (the unreacted form).

Similarly, adding chlorine solution to potassium iodide solution gives a brown (orange if it is very dilute) solution of iodine.

$$2KI(aq) + Cl_2(aq) \rightarrow 2KCl(aq) + I_2(aq)$$

In exactly the same way, the more reactive bromine displaces the less reactive iodine from potassium iodide solution. Adding bromine solution ('bromine water') to colourless potassium iodide solution gives a brown solution of iodine:

$$2KI(aq) + Br_2(aq) \rightarrow 2KBr(aq) + I_2(aq)$$



▲ Figure 9.6 Chlorine displaces bromine from potassium bromide solution.



▲ Figure 9.7 Chlorine displaces iodine from potassium iodide solution.

All of the following experiments show no reaction:

- bromine + potassium chloride solution: the less reactive bromine cannot displace the more reactive chlorine
- iodine + potassium chloride solution: the less reactive iodine cannot displace the more reactive chlorine
- iodine + potassium bromide solution: the less reactive iodine cannot displace the more reactive bromine.

IONIC EQUATIONS FOR DISPLACEMENT REACTIONS

In all of the above reactions it would not have mattered if we had reacted chlorine with *sodium* bromide or *magnesium* bromide, for example. The reaction occurs between the chlorine molecule and the bromide ion; the metal ion does not do anything, we call it a **spectator ion**. If we write the reaction between chlorine and potassium iodide showing all the charges, we can see this more clearly:

REMINDER

Remember when an ionic compound dissolves in water, it splits into its ions.

$$2K^+(aq) + 2Br^-(aq) + Cl_2(aq) \rightarrow 2K^+(aq) + 2Cl^-(aq) + Br_2(aq)$$

You can see that the potassium ions are the same on each side. They have not changed and so we can write a new equation simply concentrating on the things that have changed:

$$2Br^-(aq) + Cl_2(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$$

This is called an *ionic equation* and does not include the spectator ions.

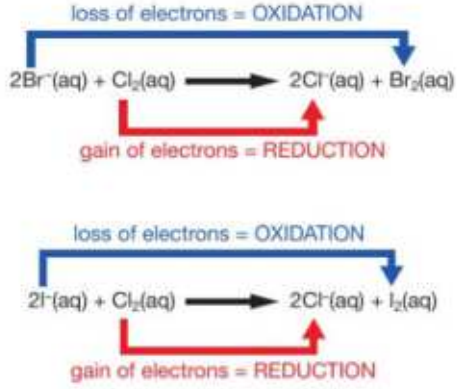
DISPLACEMENT REACTIONS AS REDOX REACTIONS

REMINDER

Some reminders about oxidation and reduction:
oxidation is loss of electrons
reduction is gain of electrons
An oxidising agent is something that oxidises something else by taking electrons away from it. Oxidising agents accept electrons and therefore are the things that are reduced in a reaction.
A reducing agent is something that reduces something else by giving electrons to it. Reducing agents give away electrons and therefore are the things that are oxidised in a reaction.

The reactions above that do show a colour change are often discussed in terms of oxidation and reduction, they are *redox reactions*. If you have not already covered redox reactions, you should look at Chapter 11 before reading the next section.

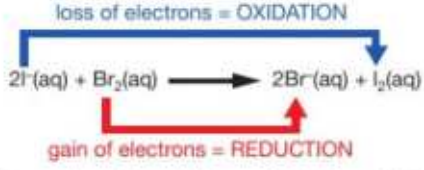
If we look at the reaction between chlorine and either bromide ions or iodide ions, we can see why they are described as redox reactions.



▲ Figure 9.8 The reaction of chlorine with potassium bromide (top) or potassium iodide (below).

In each case, the chlorine is acting as an oxidising agent. In the first equation it oxidises the Br^- ions by taking electrons away from them. Because the oxidising agent takes electrons away from something else, it is reduced itself: the Cl_2 is reduced to $2Cl^-$ ions.

In the reaction between bromine and iodide ions, the bromine is the oxidising agent:



▲ Figure 9.9 The reaction between bromine solution and potassium iodide solution.

EXTENSION WORK

This only works for non-metals. For metals, the most reactive one is the best reducing agent. The difference comes because non-metals react to form negative ions but metals react to form positive ions.

EXTENSION WORK

We can now say a bit more than just 'chlorine is more reactive than bromine, which is more reactive than iodine'. We can describe the reactivity in terms of how good an oxidising agent something is: chlorine is a stronger oxidising agent than bromine, which is a stronger oxidising agent than iodine. Chlorine can oxidise (take electrons away from) bromide ions and iodide ions; bromine can oxidise (take electrons away from) iodide ions, but not chloride ions; iodine cannot oxidise bromide ions or chloride ions.

SUMMARISING THE MAIN FEATURES OF THE GROUP 7 ELEMENTS

Group 7 elements:

- have diatomic molecules, X_2 (e.g. F_2, Cl_2, Br_2)
- go from gases to liquid to solid as you move down the group: the melting points and boiling points increase down the group
- have coloured poisonous vapours: the colours of the elements get darker down the group
- form compounds with the formula HX (e.g. HF, HCl, HBr) when reacted with hydrogen and these dissolve in water to form acids
- form ionic salts with metals and covalent compounds with non-metals
- form X^- (e.g. F^-, Cl^-, Br^-) ions in ionic compounds
- become less reactive towards the bottom of the group
- will displace elements lower down the group from their salts.

We can use these properties and trends to predict the properties of astatine, the element below iodine in Group 7. Astatine is an extremely rare radioactive element and no one has ever seen a sample of it, but we can predict that it:

- will be a darker colour than iodine, very dark grey or black
- will be a solid at room temperature and have a higher melting point than iodine
- will be diatomic and contain At_2 molecules
- will react with hydrogen to form HAt, which will dissolve in water to form an acid
- will form the salt NaAt with sodium or KAt with potassium
- will contain the astatide ion (At^-) in its ionic salts
- will be less reactive than iodine
- will be displaced from solution by iodine

CHAPTER QUESTIONS

SKILLS INTERPRETATION

SKILLS REASONING

SKILLS INTERPRETATION

SKILLS REASONING

1 a Draw a diagram to show the arrangement of electrons in a fluorine atom.

b Explain why fluorine is placed in Group 7 in the Periodic Table.

c Draw a dot-and-cross diagram (showing outer electrons only) of the molecule formed when fluorine reacts with hydrogen.

d Explain why fluorine has a lower melting point than chlorine.

e Explain what you would observe when a chlorine solution is added to a solution of potassium fluoride.

SKILLS INTERPRETATION

2 This question is about astatine, At, at the bottom of Group 7 of the Periodic Table. You are asked to make some predictions about astatine and its chemistry.

a Showing only the outer electrons, draw diagrams to show the arrangement of electrons in an astatine *atom*, an astatide *ion* and an astatine *molecule*.

SKILLS REASONING

b Explain what physical state you would expect astatine to be in at room temperature.

c Explain whether you would expect astatine to be more or less reactive than iodine.

d Suggest a likely pH for a reasonably concentrated solution of hydrogen astatide in water.

e Explain what you would expect caesium astatide to look like. Will it be soluble in water? Explain your reasoning.

SKILLS PROBLEM SOLVING, REASONING

f Write an ionic equation for the reaction that will occur if you add chlorine water to a solution of sodium astatide. Assume that astatine is insoluble in water. Explain clearly why this reaction would be counted as a redox reaction.

SKILLS PROBLEM SOLVING

3 Chlorine reacts with fluorine to form chlorine monofluoride (ClF).

a Write an equation for this reaction, including state symbols. All the substances are gases at room temperature.

SKILLS INTERPRETATION

b Draw a dot-and-cross diagram for ClF.

SKILLS REASONING

c Arrange the substances Cl_2, F_2 and ClF in order of increasing boiling point and explain your order.

SKILLS PROBLEM SOLVING

d Chlorine and fluorine can also react together to form chlorine trifluoride, which is a gas at room temperature and pressure.

i State the formula of chlorine trifluoride.

ii Chlorine trifluoride is an extremely reactive substance and, for instance, reacts explosively with water. The products of the reaction are hydrofluoric acid, hydrochloric acid and oxygen gas. Write an equation, including state symbols, for the reaction of chlorine trifluoride with water.

10 GASES IN THE ATMOSPHERE

This chapter looks at the most common gases in the atmosphere, concentrating on oxygen. We will also look at carbon dioxide, which is a greenhouse gas and may contribute to climate change.



▶ Figure 10.1 Despite the gases added by industry, the air around us is mostly nitrogen and oxygen.

LEARNING OBJECTIVES

- Know the approximate percentages by volume of the four most abundant gases in dry air
- Understand how to determine the percentage by volume of oxygen in air using experiments involving the reactions of metals (e.g. iron) and non-metals (e.g. phosphorus) with air
- Describe the combustion of elements in oxygen, including magnesium, hydrogen and sulfur
- Describe the formation of carbon dioxide from the thermal decomposition of metal carbonates, including copper(II) carbonate
- Know that carbon dioxide is a greenhouse gas and that increasing amounts in the atmosphere may contribute to climate change
- Practical: Determine the approximate percentage by volume of oxygen in air using a metal or a non-metal

THE COMPOSITION OF THE AIR

The approximate percentages (by volume) of the four most abundant gases present in *unpolluted, dry* air are shown in Table 10.1.

Table 10.1 Approximate percentages (by volume) of the main gases in unpolluted, dry air

Gas	Amount in air (%)	Amount in air (fraction)
nitrogen	78.1	about 4/5
oxygen	21.0	about 1/5
argon	0.9	
carbon dioxide	0.04	

There are also very small amounts of the other noble gases in the air.

KEY POINT

It is important to realise that these figures apply only to dry, unpolluted air. Air can have anywhere between 0 and 4% water vapour. The percentage of carbon dioxide in the air, although very small, is rising steadily because of human activity.

SHOWING THAT AIR CONTAINS ABOUT ONE-FIFTH OXYGEN

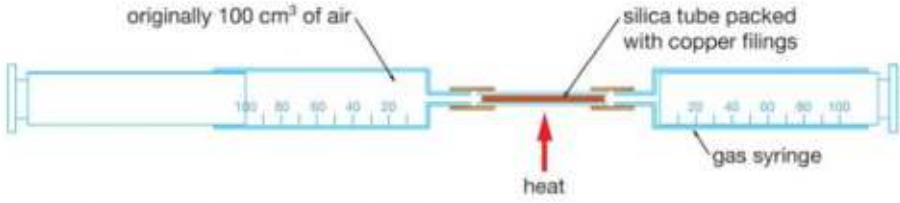
We will look at a few different methods for measuring the percentage of oxygen in the air. All the methods rely on the same basic principle: we react something with the oxygen in the air and look at how much the volume decreases as the oxygen is removed.

Safety note: Wear eye protection and heat carefully to avoid cracking the glass syringe with the flame. Take care not to push the opposite plunger completely out!.

ACTIVITY 1

▼ PRACTICAL: USING COPPER

The apparatus shown in Figure 10.2 can be used to find the percentage of oxygen in the air.



▲ Figure 10.2 Using copper to measure the percentage of oxygen in air.

- The **plunger** on one of the gas syringes is pushed all the way in and the other moved out to 100 cm^3. We now know that the apparatus contains 100 cm^3 air.
- The silica tube is heated strongly (roaring Bunsen flame).
- The plunger in the left-hand gas syringe is pushed in. This causes the air to pass over the heated copper. This pushes out the plunger on the right-hand gas syringe.
- The plungers are pushed in sequence so that the air in the system keeps passing over the heated copper. The pink-brown copper turns black as copper(II) oxide is formed.
- As the copper reacts, the Bunsen burner is moved along the tube so that it is always heating fresh copper.
- The volume of gas in the syringes falls as the oxygen is consumed.
- We keep pushing the plungers in and out until there is no change in volume.
- The apparatus is then allowed to cool to room temperature again before taking the final volume of gas (because gases expand as they are heated).

KEY POINT

When doing this experiment we need to make sure that we use enough copper to react with *all* the oxygen in the air - the copper must be in excess. There will be some unreacted copper metal at the end. If we do not use enough copper then the value we will get for the percentage of oxygen will be too low because not all of the oxygen will have been removed.

RESULTS

initial volume of air in the system / cm^3	100
final volume of 'air' in the system / cm^3	79

KEY POINT

We have put inverted commas around 'air' because we are now talking about air from which the oxygen has been removed, so it is mostly nitrogen. Nitrogen is very unreactive and so if you put a lighted splint into this 'air' it would be extinguished. Oxygen is needed for things to burn.

The volume of the air has decreased because the oxygen has been removed as it reacts with the copper. The reaction that occurs is

$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

copper + oxygen → copper(II) oxide

We can work out from these data that the volume of oxygen that reacted was 100 − 79 = 21 cm^3.

The original volume of air was 100 cm^3 so we can work out the percentage of oxygen in the air:

percentage oxygen = 21/100 × 100 = 21%

KEY POINT

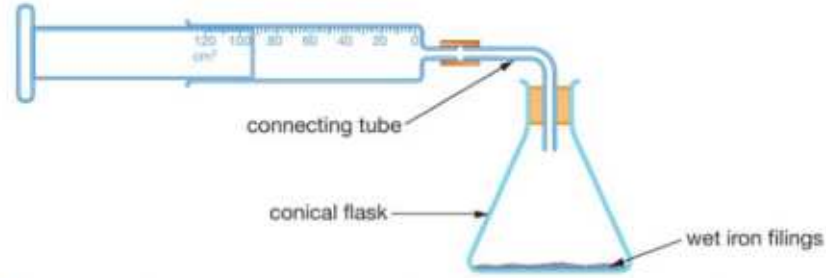
Iron needs oxygen and water to rust. The rusting of iron is discussed in Chapter 11.

Safety note: Iron filings can irritate the skin and are a particular hazard if they get in the eyes.

ACTIVITY 2

▼ PRACTICAL: USING THE RUSTING OF IRON

Iron rusts in **damp** air, using up oxygen as it does so. We can use this reaction to determine how much oxygen there is in the air.



▲ Figure 10.3 This apparatus can be used to find the percentage of oxygen in the air.

We will use the apparatus from Figure 10.3, but before we start we need to know the volume of air present in the apparatus. We can find this by filling up the conical flask and connecting tube with water and then transferring the water to a measuring cylinder. On the conical flask we mark the position of the bung and only fill with water to that point. We will assume that the small volume occupied by the **iron filings** is negligible (very small compared to the overall volume).

The procedure for the experiment is as follows:

- Set up the apparatus as shown in Figure 10.3.
- Put wet iron filings into the conical flask.
- Record the initial reading on the gas syringe.
- Leave the apparatus in place for about a week, until the reading on the gas syringe stops changing.
- Record the final reading on the gas syringe.

volume of air in conical flask / cm^3	130
volume of air in connecting tube / cm^3	12
initial reading on gas syringe / cm^3	92
final reading on gas syringe / cm^3	43

So, the total volume of air inside the apparatus at the beginning of the experiment is 130 + 12 + 92 = 234 cm^3.

The total volume of 'air' in the apparatus at the end = 130 + 12 + 43
= 185 cm^3

Volume of oxygen used up = 234 – 185 = 49 cm^3

The percentage of oxygen in the air is 49/234 × 100 = 21%.

Sometimes when you do this experiment, the answer comes out as less than 21%. Possible reasons for this could be:

- The experiment was not left set up for long enough. The iron has not had enough chance to react with all the oxygen in the apparatus.
- Not enough iron was added at the beginning. The iron must be in excess, that is, there must be enough iron to react with all the oxygen present.

KEY POINT

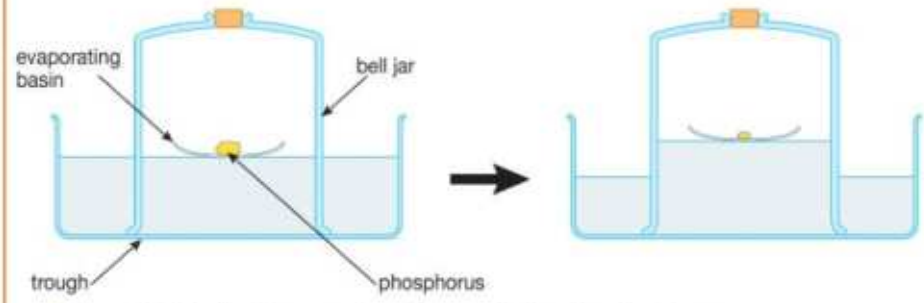
Phosphorus does not react with water.

Safety note: The teacher demonstrating needs to wear goggles or a face shield, and have the room well ventilated. After igniting the phosphorous the bell-jar needs to be held down as pressure rises initially. After all the fumes have gone the evaporating basin needs to be sunk using a glass rod to prevent any unreacted phosphorous re-igniting.

ACTIVITY 3

▼ PRACTICAL: USING PHOSPHORUS

Phosphorus is a very reactive element that reacts with the oxygen in the air to form a phosphorus oxide. This oxide is very soluble in water.



▲ Figure 10.4 Finding the percentage of oxygen in air using phosphorus.

- The apparatus shown in Figure 10.4 is set up with the piece of phosphorus on an evaporating basin, which is floating in the water.
- The initial level of water is marked on the side of the bell jar with a waterproof pen or a sticker.
- The bung is removed from the bell jar and the phosphorus is touched with a hot metal wire in order to ignite it.
- The bung is quickly put back into the bell jar.
- The phosphorus burns, the bell jar becomes filled with a white smoke (phosphorus oxide) and the level of water rises inside the bell jar. The smoke eventually clears as the phosphorus oxide dissolves in the water.
- When the level of water inside the bell jar stops rising, the final level is marked.
- To find how much the water level has changed, the bell jar is turned upside down, filled with water to each mark in turn and the water is poured into a large measuring cylinder.

It is important that there is still some phosphorus left on the evaporating basin at the end of the experiment. We have used an excess of phosphorus so that there is more than enough to react with all the oxygen. If there was no phosphorus left, then we would probably get a lower value for the percentage of oxygen in the air because not all the oxygen might have been used up.

THE COMBUSTION OF ELEMENTS IN OXYGEN

Some elements burn in oxygen, these reactions are called *combustion reactions*. Elements burn more brightly and rapidly in pure oxygen than in air because air only contains 21% oxygen.

BURNING MAGNESIUM

Magnesium burns in oxygen with an extremely bright white flame to give a white, powdery **ash** of magnesium oxide:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

The white powder formed is not very soluble in water but a very small amount does dissolve to form an alkaline solution:

$$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$$



▲ Figure 10.5 Magnesium ribbon burning in air

BURNING SULFUR

KEY POINT

Sulfur dioxide is also called sulfur(IV) oxide.

Sulfur burns in oxygen with a blue flame. Poisonous, colourless sulfur dioxide gas is produced.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$



▲ Figure 10.6 Sulfur burning in oxygen

KEY POINT

Sulfurous acid (H_2SO_3), not sulfuric acid (H_2SO_4), is formed.

The sulfur dioxide dissolves in water to form an acidic solution of *sulfurous acid*:

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$

BURNING HYDROGEN

Hydrogen burns in oxygen with a pale blue flame. The product is water:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

If you ignite a mixture of hydrogen and oxygen it will explode. This is the basis of the 'squeaky **pop**' test for hydrogen (see Chapter 14).

THE PROPERTIES OF OXIDES

We can make some generalisations about the properties of oxides formed when elements burn in oxygen.

METAL OXIDES

- Metal oxides are ionic compounds containing O^{2-} ions.
- Metal oxides are usually basic oxides, which means that they react with acids to form salts.
- Metal oxides are usually insoluble in water. Those metal oxides that are soluble in water react with it to form alkaline solutions containing hydroxide (OH^-) ions.

NON-METAL OXIDES

- Non-metal oxides are covalent compounds.
- Non-metal oxides are usually acidic oxides, which react with alkalis/bases to form salts.
- Non-metal oxides are often soluble in water and react with it to form acidic solutions containing hydrogen (H^+) ions.

CARBON DIOXIDE



▲ Figure 10.7 Copper(II) carbonate decomposes to form carbon dioxide when heated.

HINT

You should remember the colours of copper(II) carbonate and copper(II) oxide.

Carbon dioxide is a colourless gas that is most easily made in the laboratory by the reaction between dilute hydrochloric acid and calcium carbonate in the form of marble chips:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Carbon dioxide can also be obtained when metal carbonates are heated strongly.

Most carbonates split to give the metal oxide and carbon dioxide when you heat them. This is an example of **thermal decomposition**, breaking up something by heating it.

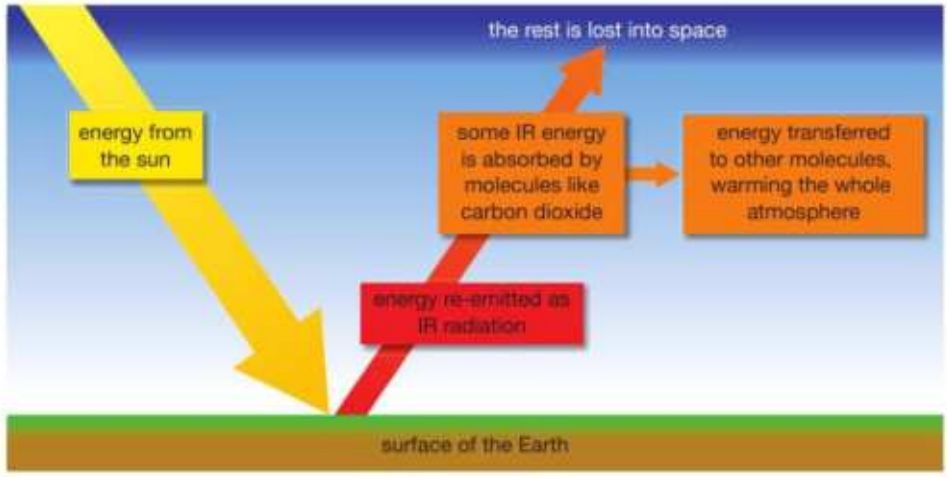
For example, copper(II) carbonate is a *green* powder which decomposes on heating to produce *black* copper(II) oxide:

$$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$$

Calcium carbonate doesn't decompose unless it is heated at quite high temperatures. This is a commercially important reaction because it is used to convert limestone (calcium carbonate) into **quicklime** (calcium oxide):

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

CARBON DIOXIDE AND GLOBAL WARMING: THE GREENHOUSE EFFECT



▲ Figure 10.8 The greenhouse effect

Carbon dioxide is produced when fossil fuels (coal, oil and gas) burn. For instance, when coal, which is mostly carbon, burns in excess oxygen:

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

REMINDER

A hydrocarbon is a molecule containing carbon and hydrogen only. These are discussed more fully in Unit 4.

Petrol is a mixture containing many different hydrocarbons. An example of a reaction that occurs when petrol burns is:

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

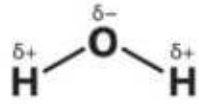
DID YOU KNOW?

Although most scientists believe that increases in carbon dioxide will cause devastating climate change, there are others who reject this. They claim that the increases in average world temperatures during the 20th century were part of natural heating and cooling cycles caused by the sun and changes to ocean currents. They believe the effect of carbon dioxide is small compared with these.

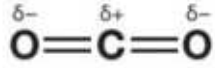
Carbon dioxide is a **greenhouse gas**. The greenhouse effect occurs when high-energy **UV** and visible light from the sun pass through the atmosphere and warm up the surface of the Earth. The surface of the Earth (like any other warm surface) radiates infrared (IR) radiation. This IR radiation is absorbed by molecules such as CO_2 in the atmosphere. These then give out this energy again in all directions, heating the atmosphere.

For approximately the last 200 years the level of CO_2 in the atmosphere has been increasing. This has occurred since the industrial revolution and is due to the burning of fossil fuels and deforestation (cutting down trees to create more land for agriculture). Many people believe that the increase in the level of carbon dioxide in the atmosphere may contribute to climate change. The exact nature of this climate change is difficult to know, but some of the things that scientists believe could happen are:

- polar ice caps could melt
- sea levels could rise
- there could be more extreme weather (such as floods, droughts and heat waves).



▲ Figure 10.9 Water is a polar molecule. The oxygen atoms attract the electrons in the covalent bonds more than the hydrogen atoms. The δ+ (delta positive) and δ– (delta negative) represent small charges on the atoms.



▲ Figure 10.10 The oxygen atoms attract the electrons in the covalent bonds more than the carbon atoms do (oxygen is more electronegative than carbon) but the charges cancel due to the shape (a better way of saying this is that the dipoles cancel).

LOOKING AHEAD

Why is CO_2 a greenhouse gas and oxygen and nitrogen are not?

The presence of greenhouse gases in the atmosphere is essential to the maintenance of life on Earth as they keep the planet at a temperature at which water is mostly a liquid. However, it is very important that we do not have too much of these greenhouse gases. If nitrogen and oxygen, the main constituents of the atmosphere, were greenhouse gases the temperature of the Earth would be too high to support life as we know it. So, what makes something a greenhouse gas? A greenhouse gas must be able to **absorb** IR radiation emitted by the surface of the Earth and then emit it again in all directions, warming the atmosphere. All molecules vibrate and if these vibrations involve a change in the polarity of the molecule then the molecule will be able to absorb IR radiation and be a greenhouse gas.

What is polarity? A molecule is polar if one end of the molecule is slightly negative and the other end is slightly positive. Polarity arises because different atoms attract the electrons in a covalent bond to different extents (this is a property called *electronegativity*). The polarity also depends on the shape of the molecule. Water is a good example of a polar molecule.

The polarity of a water molecule changes as it vibrates and water vapour is an important greenhouse gas.

Carbon dioxide is a non-polar molecule because it is linear (the atoms are in a straight line) and symmetrical, and therefore there is no positive end and no negative end of the molecule.

However, as a CO_2 molecule vibrates it becomes non-symmetrical and polar. Because the polarity changes as a CO_2 molecule vibrates it can absorb IR radiation and is a greenhouse gas.

O_2 and N_2 are non-polar because both the atoms are the same and therefore attract the electrons in the covalent bonds equally, so there are no small charges. The molecules can only vibrate in one way and the molecules remain non-polar as they vibrate. This means that there is no change in polarity as they vibrate, therefore N_2 and O_2 cannot absorb IR radiation and are not greenhouse gases.

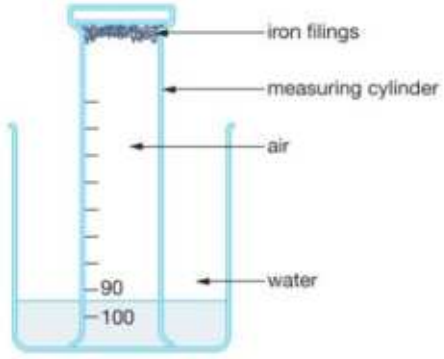
CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 State the approximate percentage of each of the following gases in dry air:
a nitrogen b oxygen c carbon dioxide d argon

SKILLS PROBLEM SOLVING

2 A student carried out an experiment to measure the percentage oxygen in the air by using the rusting of iron. The experimental set-up is shown below. The initial reading on the measuring cylinder was 95 cm^3. They left the apparatus for 2 days and the new reading on the measuring cylinder was 80 cm^3.



a Calculate the percentage oxygen in the air using this data.

SKILLS REASONING, DECISION MAKING

b Explain why the answer is not the same as you had expected and how the experiment could be improved.

SKILLS DECISION MAKING

3 A student carries out an experiment to investigate how much gas is produced when various metal carbonates are heated. Their data are shown in the table.

Metal carbonate	Mass of carbonate used / g	Volume of gas collected at rtp / cm^3	Mass of solid left at the end / g
lead(II) carbonate	1.00	89	0.84
copper(II) carbonate	1.00	194	0.64
sodium carbonate	1.00	0	1.00

a Describe an experiment that would allow the student to collect these data.

SKILLS CRITICAL THINKING

b Name the gas collected.

SKILLS PROBLEM SOLVING

c Write an equation for the reaction occurring with lead(II) carbonate.

SKILLS CRITICAL THINKING

d Name the type of reaction occurring with lead(II) carbonate and copper(II) carbonate.

SKILLS REASONING

e Explain what these results indicate about the thermal **stability** of sodium carbonate compared to the other two substances.

f Explain why much more gas is given off in the copper(II) carbonate experiment than in the lead(II) carbonate experiment.

SKILLS PROBLEM SOLVING

g Use the data from the lead(II) carbonate experiment to calculate the mass of 100 cm^3 of the gas.

SKILLS EXECUTIVE FUNCTION

h The student repeated the experiment for copper(II) carbonate and only obtained 152 cm^3 of gas this time. Explain two things that could have gone wrong with the second experiment to give this result.

SKILLS CRITICAL THINKING

4 Carbon dioxide is described as a *greenhouse gas*. Explain what this means.

11 REACTIVITY SERIES

The reactivity series lists elements (mainly metals) in order of decreasing reactivity. It is likely that you will have come across some of this chemistry already in earlier years. This chapter looks at some of the reactions of metals and introduces the idea of redox reactions.



▲ Figure 11.1 Rails are welded together using molten iron, produced by a reaction between aluminium and iron(III) oxide.



▲ Figure 11.2 Gold is so unreactive that it will remain chemically unchanged in contact with air or water basically forever.

LEARNING OBJECTIVES

- Understand how metals can be arranged in a reactivity series based on their reactions with:
  - water
  - dilute hydrochloric or sulfuric acid
- Understand how metals can be arranged in a reactivity series based on their displacement reactions between:
  - metals and metal oxides
  - metals and aqueous solutions of metal salts
- Know the order of reactivity of these metals: potassium, sodium, lithium, calcium, magnesium, aluminium, zinc, iron, copper, silver, gold
- Know the conditions under which iron rusts
- Understand how the rusting of iron may be prevented by:
  - barrier methods
  - galvanising
  - sacrificial protection
- Understand the terms:
  - oxidation
  - reduction
  - redox
  - oxidising agent
  - reducing agent

  in terms of gain or loss of oxygen and loss or gain of electrons
- Practical: Investigate reactions between dilute hydrochloric and sulfuric acids and metals (e.g. magnesium, zinc and iron)

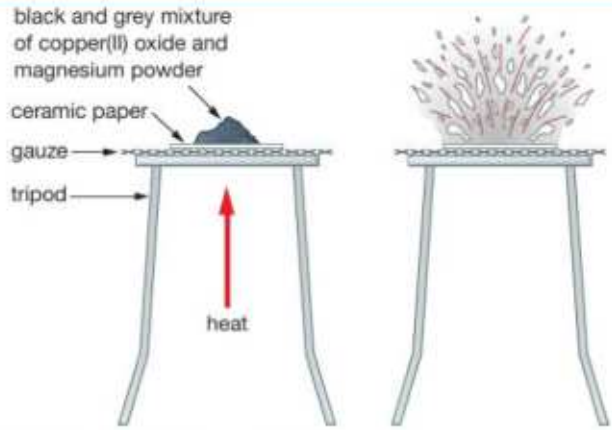
DISPLACEMENT REACTIONS INVOLVING METAL OXIDES

THE REACTION BETWEEN MAGNESIUM AND COPPER(II) OXIDE

potassium
sodium
lithium
calcium
magnesium
aluminium
(carbon)
zinc
iron
(hydrogen)
copper
silver
gold

decreasing reactivity

▲ Figure 11.4 The reactivity series. Although carbon and hydrogen are not metals they are usually included in the series. You will learn why in this chapter.



▲ Figure 11.3 Magnesium reacts with copper(II) oxide.

Safety note: For this demonstration goggles or a face shield are needed, together with safety screens in a well-ventilated room. The bench should be protected by a large sheet of hardboard. The pupils should be at the back of the room. One gram of the mixture is strongly heated in a metal crown bottle cap before retiring to the back of the room to await a violent reaction. If nothing happens after a minute or so turn off the gas and do not touch the mixture but leave it to cool and dispose of it in water.

Magnesium powder and copper(II) oxide are mixed together and heated very strongly. At the end, **traces** of white magnesium oxide are left on the ceramic paper.

magnesium + copper(II) oxide → magnesium oxide + copper

$Mg(s) + CuO(s) \rightarrow MgO(s) + Cu(s)$

This is an example of a displacement reaction. The less reactive metal, copper, has been displaced from its compound by the more reactive magnesium. Any metal higher in the **reactivity series** will displace one lower down from a compound.

If you heated copper with magnesium oxide, nothing would happen because copper is less reactive than magnesium. Copper isn't capable of displacing magnesium from magnesium oxide.

KEY POINT

These reactions involving metals and metal oxides are often called **competition reactions**.

THE REACTION BETWEEN MAGNESIUM AND ZINC OXIDE

Heating magnesium with zinc oxide produces zinc metal:

magnesium + zinc oxide → magnesium oxide + zinc

$Mg(s) + ZnO(s) \rightarrow MgO(s) + Zn(s)$

THE REACTION BETWEEN CARBON AND COPPER(II) OXIDE

Safety note: Wear eye protection. The tube will get very hot and remain so for some time.

A black mixture of carbon and copper(II) oxide is heated in a test-tube. The mixture **glows** red hot because of the heat given out during the reaction, and you are left with pink-brown copper in the tube.

$C(s) + 2CuO(s) \rightarrow CO_2(g) + 2Cu(s)$

Carbon is above copper in the reactivity series and displaces the copper from copper(II) oxide.

OXIDATION AND REDUCTION

OXYGEN TRANSFER

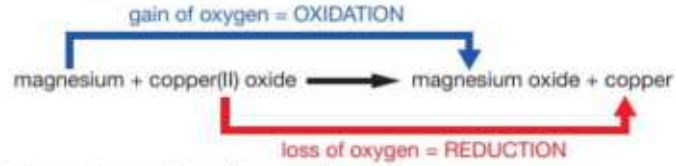
DID YOU KNOW?

Many metals are found as metal oxides in nature. If they are found as other compounds these are often converted to metal oxides before the metal is extracted.

A substance has been oxidised if it gains oxygen. **Oxidation** is gain of oxygen.

A substance has been reduced if it loses oxygen. **Reduction** is loss of oxygen.

Consider the reaction between magnesium and copper(II) oxide again. Figure 11.5 shows what happens in terms of oxidation and reduction.



▲ Figure 11.5 Magnesium reacting with copper(II) oxide

A **redox** reaction is one in which both **red**uction and **ox**idation are occurring. Oxidation and reduction always occur together because if something loses oxygen, something else must gain it.

- A **reducing agent** is a substance that reduces something else. In this case, the magnesium is the reducing agent because it takes the oxygen away from the copper oxide, reducing it.
- An **oxidising agent** is a substance that oxidises something else. The copper(II) oxide is the oxidising agent in this reaction because it gives oxygen to the magnesium, oxidising it.

An oxidising agent always gets reduced in a chemical reaction because it oxidises something else by giving away its oxygen.

A reducing agent always gets oxidised in a chemical reaction because it takes the oxygen away from something else and therefore gains oxygen itself.

In the reaction between magnesium and zinc oxide on page 367, the magnesium is the reducing agent and the zinc oxide is the oxidising agent. In the reaction between copper(II) oxide and carbon, the carbon is the reducing agent and the copper(II) oxide is the oxidising agent.

ELECTRON TRANSFER

We are now going to look very closely at what happens in the reaction between magnesium and copper(II) oxide in terms of the various particles involved. Here is the equation again:

$$Mg(s) + CuO(s) \rightarrow MgO(s) + Cu(s)$$

The magnesium and the copper are metals, and are made of metal atoms, but the copper(II) oxide and the magnesium oxide are both ionic compounds.

The copper(II) oxide contains Cu^{2+} and O^{2-} ions, and the magnesium oxide contains Mg^{2+} and O^{2-} ions. Writing these into the equation gives:

$$Mg(s) + Cu^{2+}O^{2-}(s) \rightarrow Mg^{2+}O^{2-}(s) + Cu(s)$$

The oxide ion (O^{2-}) does not change in this reaction. It ends up with a different partner, but is totally unchanged itself.

What is happening in this reaction is that magnesium *atoms* are turning into magnesium *ions*. The magnesium atoms lose electrons to form magnesium ions. These electrons are gained by the copper ions to form copper atoms. We have described this as a redox reaction above in terms of loss/gain of oxygen, but now we can see that it was not the oxygen that was actually the important part, it has not changed! To understand what is happening better, we need a more fundamental definition of oxidation and reduction:

- *oxidation is loss of electrons*
- *reduction is gain of electrons.*

The mnemonic OILRIG can be helpful in remembering this:

Oxidation

Is

Loss of electrons

Reduction

Is

Gain of electrons

DISPLACEMENT REACTIONS INVOLVING SOLUTIONS OF SALTS

Salts are compounds such as copper(II) sulfate, silver nitrate or sodium chloride. You will find a definition of what a salt is on page 386. This section explores some reactions between metals and solutions of salts in water.

THE REACTION BETWEEN ZINC AND COPPER(II) SULFATE SOLUTION

The copper is displaced by the more reactive zinc. The blue colour of the copper(II) sulfate solution **fades** as colourless zinc sulfate solution is formed:

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

The zinc and the copper are metals consisting simply of atoms, but the copper(II) sulfate and the zinc sulfate are metal compounds and so are ionic.

The equation can be rewritten showing the ions:

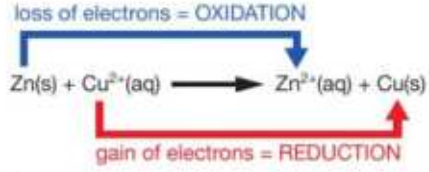
$$Zn(s) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Zn^{2+}(aq) + SO_4^{2-}(aq) + Cu(s)$$

We can see that the sulfate ions are exactly the same on both sides of the equation – they have not changed at all in the reaction. We call the sulfate ions here *spectator ions*. Removing the spectator ions (because they aren't changed during the reaction) leaves:

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

This is called an ionic equation and just shows the things that change in the reaction.

This is another redox reaction.



▲ Figure 11.6 The reaction between zinc and copper(II) sulfate solution

The Zn atoms are oxidised to Zn^{2+} ions because they lose electrons. The Cu^{2+} ions gain electrons and are reduced to Cu atoms. We can split up the ionic equation to show the individual oxidation and reduction processes:

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^- \quad \text{oxidation}$$

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s) \quad \text{reduction}$$

These are called *ionic* ***half-equations*** as they each only show one of the processes (either oxidation or reduction) occurring in the reaction. In reality, these processes cannot occur one without the other: if something gains electrons, it has to get them from somewhere, so something else must lose electrons.

KEY POINT

When we looked at the reaction between Mg and CuO above, we also wrote ions in the equation but we did not separate them completely because the ions are in a solid. We only separate everything like this when things are in solution. In a solution the ions are free to move around separately, in a solid they are not.

KEY POINT

Which copper(II) salt you started with would not matter, as long as it was soluble in water. Copper(II) chloride or copper(II) nitrate would react in exactly the same way with zinc because the chloride ions or the nitrate ions would again be spectator ions, not participating in the reaction.

OXIDISING AND REDUCING AGENTS IN TERMS OF ELECTRONS

A couple more definitions (this time in terms of electrons):

- *An oxidising agent is something that oxidises something else by taking electrons away from it. Oxidising agents accept electrons and therefore are reduced in a reaction.*
- *A reducing agent is something that reduces something else by giving electrons to it. Reducing agents give away electrons and therefore are oxidised in a reaction.*

HINT

You now have two definitions of oxidation (and its reverse, reduction). Which one should you use? Use whichever is simpler in the case you are asked about! Both definitions are true. Don't worry too much about this at the moment. With a little experience, you will find it is obvious which one you need to use in various cases.

Let us look again at the overall ionic equation for the displacement reaction between zinc and copper ions:

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

The Zn reduces the Cu^{2+} by giving electrons to it and therefore the Zn is the reducing agent. In the process of the reaction the Zn is oxidised because it has given electrons away (lost them).

The Cu^{2+} oxidises the Zn by taking electrons away from it, therefore the Cu^{2+} is the oxidising agent. In the process the Cu^{2+} is reduced because it has taken electrons (gained them).



▲ Figure 11.7 Displacing silver from silver nitrate solution

THE REACTION BETWEEN COPPER AND SILVER NITRATE SOLUTION

Silver is below copper in the reactivity series, so a **coil** of copper wire in silver nitrate solution will produce metallic silver. Figure 11.7 shows the silver being produced as a mixture of grey 'fur' and delicate crystals. Notice the solution becoming blue, as copper(II) nitrate is produced:

$$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$$

This time the nitrate ions are spectator ions, and the final version of the ionic equation looks like this:

$$Cu(s) + 2Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$

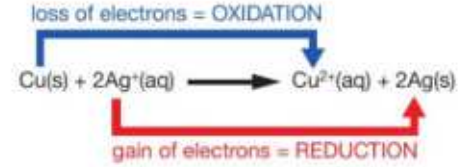
This is another redox reaction.

The Cu is the reducing agent (it is oxidised) because it gives electrons to the Ag^{+} ions to reduce them to Ag. The Ag^{+} ion is the oxidising agent (it is reduced) because it takes electrons away from the Cu atoms.

The ionic half-equations are:

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^{-} \quad \text{oxidation}$$

$$Ag^{+}(aq) + e^{-} \rightarrow Ag(s) \quad \text{reduction}$$



▲ Figure 11.8 Copper reacting with silver nitrate solution

REACTIONS OF METALS WITH WATER

A GENERAL SUMMARY

METALS ABOVE HYDROGEN IN THE REACTIVITY SERIES

Metals above hydrogen in the reactivity series react with water (or steam) to produce hydrogen.

If the metal reacts with *cold water*, the metal *hydroxide* and hydrogen are formed.

metal + cold water → metal hydroxide + hydrogen

If the metal reacts with *steam*, the metal *oxide* and hydrogen are formed.

metal + steam → metal oxide + hydrogen

As you move down the reactivity series, the reactions become less and less vigorous.

METALS BELOW HYDROGEN IN THE REACTIVITY SERIES

Metals below hydrogen in the reactivity series (such as copper) don't react with water or steam. This is why copper can be used for both hot and cold water pipes.

REACTIONS OF POTASSIUM, SODIUM OR LITHIUM WITH COLD WATER

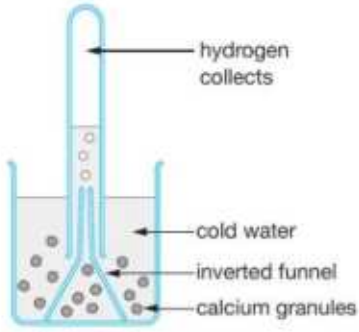
These reactions are described in detail on pages 347–348. They are very vigorous reactions, but become less violent in the following order: potassium > sodium > lithium. The equations all look like this:

$$2M(s) + 2H_2O(l) \rightarrow 2MOH(aq) + H_2(g)$$

Replace M by K, Na or Li, depending on which metal you want.

REACTION OF CALCIUM WITH COLD WATER

Calcium reacts gently with cold water. The grey granules sink, but are carried back to the surface again as bubbles of hydrogen are formed around them. The mixture becomes warm as heat is produced.



▲ Figure 11.9 Calcium reacting with cold water

Calcium hydroxide is formed. This isn't very soluble in water. Some of it dissolves to give a colourless solution, but most of it is left as a white, insoluble solid.

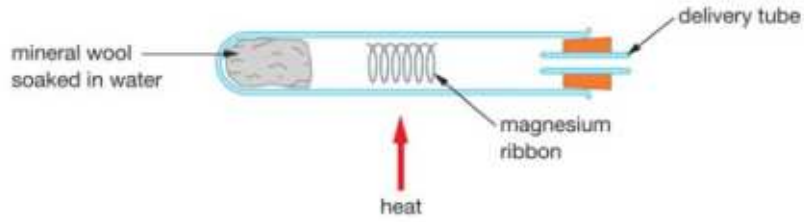
$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq \text{ or } s) + H_2(g)$$

REACTION OF MAGNESIUM WITH COLD WATER

There is almost no reaction. If the magnesium is very clean, a few bubbles of hydrogen form on it, but the reaction soon stops again. This is because the magnesium becomes coated with insoluble magnesium hydroxide, which prevents any more water coming into contact with the magnesium.

REACTION OF MAGNESIUM WITH STEAM

Magnesium ribbon can be heated in steam using the apparatus shown in Figure 11.10.



▲ Figure 11.10 Magnesium reacting with steam

The mineral wool isn't heated directly. Enough heat moves back along the test-tube to turn the water to steam.

The magnesium burns with a bright white flame in the steam, producing hydrogen, which can be ignited at the end of the delivery tube. White magnesium oxide is formed:

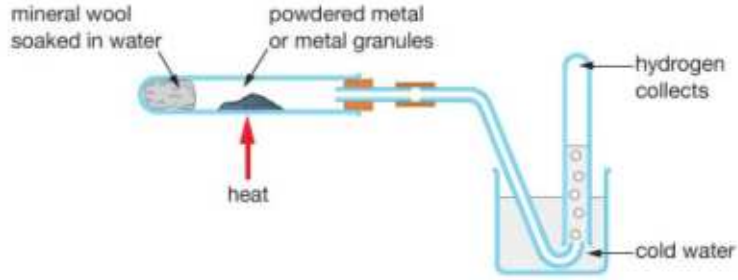
$$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$$

KEY POINT

You might wonder why there is no description for aluminium and steam. The reactivity of aluminium is supposed to be between that of magnesium and that of zinc. However, aluminium has only a very slow reaction with steam because it is covered in a very thin, but very strong, layer of aluminium oxide. It only really shows its true reactivity if that layer can be penetrated in some way. Water or steam don't do that very well. We will talk about this again when we look at reactions between metals and acids.

REACTIONS OF ZINC OR IRON WITH STEAM

Safety note: For both reactions wear eye protection. The tube will get very hot and remain so for some time.



▲ Figure 11.11 Zinc or iron reacting with steam

KEY POINT

Care has to be taken during this experiment to avoid 'suck-back'. If you stop heating while the delivery tube is still under the surface of the water, water is sucked back into the hot tube, which often results in it cracking.

With both zinc and iron, the hydrogen comes off slowly enough to be collected. Neither metal burns.

WITH ZINC

Zinc oxide is formed. This is yellow when it is hot, but white on cooling.

$$Zn(s) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$$

WITH IRON

The iron becomes slightly darker grey. A complicated oxide is formed, called tri-iron tetroxide, Fe_3O_4:

$$3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$$

KEY POINT

Notice that in these equations, water now has a state symbol (g) because we are talking about it as steam.

REMINDER

Remember that *metals below hydrogen* in the reactivity series, such as copper, *don't react* with water or steam.

REACTIONS OF METALS WITH DILUTE ACIDS

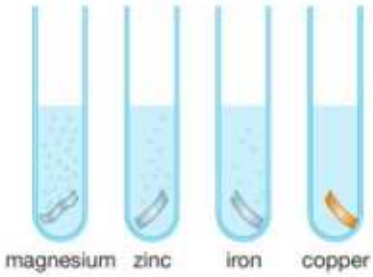
Safety note: Wear eye protection. Keep hands and face away from the mouths of the tubes as some acid aerosol (tiny droplets) may be carried out by the gas.

ACTIVITY 4

▼ PRACTICAL: INVESTIGATION INTO THE REACTIONS BETWEEN METALS AND DILUTE ACIDS

- Set up four test-tubes and put about 2 cm^3 of dilute hydrochloric acid into each one.
- Put a small piece of magnesium, zinc, iron or copper into each test-tube and observe any reaction that occurs.
- If there is fizzing, collect or trap the gas and test with a lighted splint – a squeaky pop indicates the presence of hydrogen gas.
- Repeat the experiments with dilute sulfuric acid.

The results that we could obtain from the experiments with dilute hydrochloric acid are shown in Figure 11.12 and Table 11.1.



▲ Figure 11.12 The reactions between metals and hydrochloric acid

Table 11.1 The results of experiments on the reaction between hydrochloric acid and some metals

Metal	Reaction with dilute hydrochloric acid
Magnesium	Reacts vigorously with lots of fizzing. The gas produced gave a squeaky pop with a lighted splint. A colourless solution is formed. The test-tube gets hot.
Zinc	Steady reaction. Fizzing. Enough gas eventually collected to produce a squeaky pop with a lighted splint. A colourless solution formed. The test-tube gets warmer.
Iron	Slow fizzing. Very little gas was collected in the time available. A very pale green solution formed. The test-tube got slightly warmer.
Copper	No change.

These reactions are all **exothermic** (they give out heat). See Chapter 15 for more about exothermic reactions.

Now that we have noticed that there is a temperature change in the reaction we could measure this temperature change to compare the reactivity of the metals. However, in order to do this we will have to think more carefully about the things that we have to keep the same in order to make this a valid (fair) test.

The volume and concentration of the hydrochloric acid are perhaps the most obvious things that we have to keep the same, but what about the mass of the metal? This is a more difficult question. If we use 0.24 g of metal in each experiment, we can work out that this is 0.24/24 = 0.010 mol magnesium but 0.24/56 = 0.0040 mol iron.

KEY POINT

If the reaction occurs very slowly, the heat will be given out over a long period of time. As the heat is being given out it will also be lost to the surroundings and the temperature change will be quite low. If the reaction occurs more quickly, the heat is given out more quickly to the solution, and there is less time for heat to be lost to the surroundings – we obtain a larger temperature change. A large surface area causes a faster rate of reaction, so we should use metal powders in these reactions. These things are discussed more in Chapters 15 and 16.

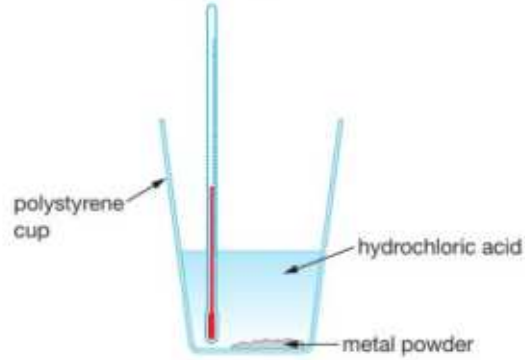
Safety note: Wear eye protection and avoid splashing the acid when stirring.

Now, chemical reactions depend on how many particles are present: more moles and therefore more particles are present in the Mg experiment and more heat would be given out because of this. It is therefore important that we use the same number of moles in each experiment rather than the same number of grams.

The other variable that we should control is the surface area of the metal. Although this does not affect the overall amount of heat given out in the reaction, it will affect the speed at which the heat is given out, which can affect the temperature change.

We will use the following procedure to investigate this reaction quantitatively (involving numbers):

- Measure out 50 cm^3 of 1 mol/dm^3 hydrochloric acid using a 50 cm^3 measuring cylinder (this amount was chosen so that the hydrochloric acid is in excess – there is more than enough to react with all the metal in each case).
- **Pour** the hydrochloric acid into a polystyrene cup (this is an insulator).
- Measure the initial temperature of the hydrochloric acid.
- Weigh out 0.010 mol of magnesium (0.010 × 24 = 0.24 g) powder.
- Add the magnesium powder to the polystyrene cup, stirring rapidly, and measure the maximum temperature reached.
- Repeat with the other metals using 0.010 mol in each case.

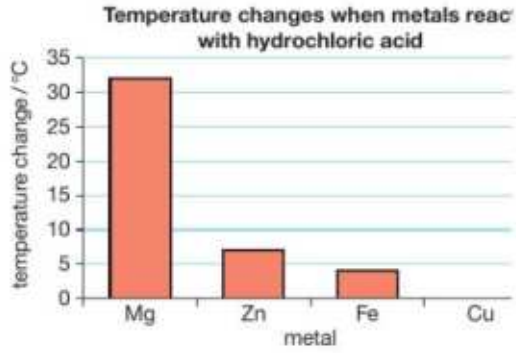


▲ Figure 11.13 Measuring the temperature change when a metal reacts with dilute hydrochloric acid.

The data for this experiment could be:

Metal	Mass / g	Initial temperature / °C	Maximum temperature / °C
magnesium	0.24	18	40
zinc	0.65	19	26
iron	0.56	18	22
copper	0.64	18	18

We can work out the temperature change for each experiment and plot this as a bar chart. We use a bar chart because the type of metal is not continuous data: the metal can be either magnesium or zinc, it cannot be anything in between.



▲ Figure 11.14 Magnesium gives out the most heat when reacted with hydrochloric acid.

We can see from this data that magnesium caused the greatest temperature change and so is the most reactive metal of the four; copper caused no change and is the least reactive.

KEY POINT

We could also calculate the molar enthalpy change for each reaction – see Chapter 15 to learn how to do this.

KEY POINT

The general trends on this page apply to simple acids such as dilute sulfuric acid or dilute hydrochloric acid. Nitric acid and concentrated sulfuric acid behave completely differently with most metals. These are problems beyond International GCSE.

A GENERAL SUMMARY

The pattern for the reaction of metals with acids is the same as for the reaction between the metals and water, but in each case the reaction is much more vigorous.

METALS ABOVE HYDROGEN IN THE REACTIVITY SERIES

Metals above hydrogen react with acids to form a salt (e.g. magnesium sulfate or zinc chloride) and hydrogen. The higher the metal in the series, the more violent the reaction.

HINT

You can remember this using the mnemonic MASH.

metal + acid → salt + hydrogen

metal + dilute sulfuric acid → metal sulfate + hydrogen

metal + dilute hydrochloric acid → metal chloride + hydrogen

METALS BELOW HYDROGEN IN THE REACTIVITY SERIES

Metals such as copper, silver and gold do not react with simple dilute acids such as sulfuric or hydrochloric acid.

POTASSIUM, SODIUM, LITHIUM AND CALCIUM WITH DILUTE ACIDS

These are too reactive to add safely to acids, the reaction is too violent. Calcium can be used if the acid is very dilute.

METALS FROM MAGNESIUM TO IRON IN THE REACTIVITY SERIES

Safety note: Wear eye protection and avoid splashing the acid when stirring.

Magnesium reacts vigorously with cold dilute acids, and the mixture becomes hot. A colourless solution of magnesium sulfate or chloride is formed. With dilute sulfuric acid:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

Aluminium is slow to start reacting, but after warming it reacts very vigorously. There is a very thin, but very strong, layer of aluminium oxide on the surface of the aluminium, which stops the acid from getting to it. On heating, the acid removes this layer, and the aluminium can show its true reactivity. With dilute hydrochloric acid:

$$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$$

Zinc and ***iron*** react slowly in the cold, but more rapidly on heating. The vigour of the reactions is less than that of aluminium. The zinc forms zinc sulfate or zinc chloride and hydrogen. The iron forms iron(II) sulfate or iron(II) chloride and hydrogen. For example:

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$
$$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

KEY POINT

There are two ranges of iron salts containing either Fe^{2+} or Fe^{3+} ions. These reactions produce iron(II) salts, containing Fe^{2+} ions.



▲ Figure 11.15 Iron reacting with dilute hydrochloric acid

FINDING THE APPROXIMATE POSITION OF A METAL IN THE REACTIVITY SERIES USING WATER AND DILUTE ACIDS

KEY POINT

It would be impossible to place a metal exactly in the reactivity series using this sequence. How vigorously a metal reacts with a dilute acid depends on its position in the series, but it also depends on its surface area, and whether the surface is free from dirt or an oxide coating.

Add a very small piece of metal to some cold water. If there is any rapid reaction, then the metal must be above magnesium in the reactivity series.

If there isn't any reaction, add a small amount of metal to some dilute hydrochloric acid (or dilute sulfuric acid). If there isn't any reaction in the cold acid, warm it carefully.

If there is still no reaction, the metal is probably below hydrogen in the reactivity series. If there is a reaction, then it is somewhere between magnesium and hydrogen.

MAKING PREDICTIONS USING THE REACTIVITY SERIES

You can make predictions about the reactions of unfamiliar metals if you know their position in the reactivity series.

A PROBLEM INVOLVING MANGANESE

KEY POINT

You need to know the charge on the ion so that you can deduce the formulae of the manganese compounds. If you aren't sure about working out the formula of an ionic compound, look again at Chapter 6.

Suppose you have a question as follows.

Manganese (Mn) lies between aluminium and zinc in the reactivity series, and forms a 2+ ion. Solutions of manganese(II) salts are very pale pink (almost colourless).

a Use the reactivity series to predict whether manganese will react with copper(II) sulfate solution. If it will react, describe what you would see, name the products and write an equation for the reaction.

b Explain why you would expect manganese to react with steam. Name the products of the reaction and write the equation.

potassium
sodium
lithium
calcium
magnesium
aluminium
manganese
zinc
iron
(hydrogen)
copper

▲ Figure 11.16 Where is manganese in the reactivity series?

a The reaction between manganese and copper(II) sulfate solution

Manganese is above copper in the reactivity series and so will displace it from the copper(II) sulfate:

A pink-brown deposit of copper will be formed. The colour of the solution will fade from blue and leave a very pale pink (virtually colourless) solution of manganese(II) sulfate.

$$Mn(s) + CuSO_4(aq) \rightarrow MnSO_4(aq) + Cu(s)$$

b The reaction between manganese and steam

Manganese is above hydrogen in the reactivity series and so reacts with steam to give hydrogen and the metal oxide, in this case manganese(II) oxide.

You couldn't predict the colour of the manganese(II) oxide, and the question doesn't ask you to do this.

$$Mn(s) + H_2O(g) \rightarrow MnO(s) + H_2(g)$$

RUSTING OF IRON

HINT

Warning! Many metals corrode, but it is only the corrosion of iron that is referred to as *rusting*.

Iron **rusts** in the presence of *oxygen* and *water*. Rusting occurs with iron and the most common **alloy** of iron, mild steel (see below).

The formula of rust is $Fe_2O_3 \cdot xH_2O$, where x is a variable number. It can be called 'hydrated iron(III) oxide'. Rusting can be described as a redox reaction – the iron is oxidised.

KEY POINT

Forming rust from iron is a surprisingly complicated process. The iron loses electrons to form iron(II) ions, Fe^{2+}, which are then oxidised by the air to iron(III) ions, Fe^{3+}. Reactions involving the water produce the actual rust.



▲ Figure 11.17 Rusting is accelerated by salty water.

PREVENTING RUSTING BY USING BARRIERS

The most obvious way of preventing rusting is to keep water and oxygen away from the iron. You can do this by painting it, coating it in oil or grease, or covering it in plastic. Coating the iron with a metal *below* it in the reactivity series (e.g. coating steel with tin for tin cans) is also a **barrier method**.

Barrier methods are usually quite cheap ways of preventing rusting. A problem with barrier methods is that once the coating is broken, the iron underneath is exposed to oxygen and water and the iron will rust (even the bits that are not directly exposed to the air/water).

PREVENTING RUSTING BY GALVANISING

Galvanised iron is iron that is coated with a layer of zinc. As long as the zinc layer is unscratched, it serves as a barrier to air and water. However, the iron still doesn't rust, even when some of the zinc on the surface is scratched away

EXTENSION WORK

During the process, the zinc loses electrons (is oxidised) to form zinc ions.

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

These electrons flow into the iron. Any iron atom which has lost electrons to form an ion immediately regains them. If the iron can't form ions, it can't rust.

to expose the iron. This is because the zinc is more reactive than iron, and so reacts with oxygen/water more readily than the iron does. The zinc corrodes instead of the iron.



▲ Figure 11.18 Galvanised iron doesn't rust even in constant contact with air and water.

PREVENTING RUSTING BY USING SACRIFICIAL PROTECTION



▲ Figure 11.19 A sacrificial anode on a ship

Zinc, magnesium or aluminium blocks are attached to metal hulls or keels of ships to prevent the iron/steel from rusting. For this to work, you have to use a metal that is *more reactive than iron;* the more reactive metal reacts (is oxidised) more readily in the presence of oxygen/water than the iron. The corrosion of the more reactive metal prevents the iron from rusting. Such blocks are called sacrificial **anodes**.

These sacrificial anodes have to be replaced occasionally when all the more reactive metal has been oxidised. This type of protection is used on large structures where it would be very difficult to use a barrier method effectively.

Galvanising is a combination of a barrier method and **sacrificial protection**.

Underground pipelines are also protected using sacrificial anodes. In this case, **lumps** of magnesium are attached at intervals along the pipe. The very reactive magnesium corrodes in preference to the iron. The electrons produced as the magnesium forms its ions prevent the ionisation of the iron.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 a List the following metals in order of decreasing reactivity: aluminium, copper, iron, sodium.

b Some magnesium powder was mixed with some copper(II) oxide and heated strongly. There was a vigorous reaction, producing a lot of sparks and a bright **flash** of light.

i State the names of the products of the reaction.

SKILLS PROBLEM SOLVING

ii Write a balanced symbol equation for the reaction.

SKILLS REASONING

iii Explain which substance in the reaction has been reduced.

iv Explain which substance is the oxidising agent.

c If a mixture of zinc powder and cobalt(II) oxide is heated, the following reaction occurs:

$$Zn(s) + CoO(s) \rightarrow ZnO(s) + Co(s)$$

i Explain which metal is higher in the reactivity series.

SKILLS CRITICAL THINKING

ii The zinc can be described as a reducing agent. Using this example, explain what is meant by the term 'reducing agent'.

iii Explain which substance in this reaction has been oxidised.

SKILLS REASONING

d Aluminium, chromium and manganese are all moderately reactive metals. Use the following information to arrange them in the correct reactivity series order. Start with the most reactive one.

- Chromium is manufactured by heating chromium(III) oxide with aluminium.
- If manganese is heated with aluminium oxide there is no reaction.
- If manganese is heated with chromium(III) oxide, chromium is produced.

2 Study the following equations and in each case decide whether the substance in bold type is oxidised or reduced. Explain your choice in terms of either oxygen transfer or electron transfer as appropriate.

a **Zn(s)** + CuO(s) → ZnO(s) + Cu(s)

b **Fe_2O_3(s)** + 3C(s) → 2Fe(s) + 3CO(g)

c **Mg(s)** + Zn^{2+}(aq) → Mg^{2+}(aq) + Zn(s)

d Zn(s) + **Cu^{2+}(aq)** → Zn^{2+}(aq) + Cu(s)

3 The equation for the reaction when solid magnesium and solid lead(II) oxide are heated together is:

Mg(s)+ PbO(s) → MgO(s) + Pb(s)

Explain what this tells you about the position of lead in the reactivity series.

4 Some iron filings were shaken with some copper(II) sulfate solution. The ionic equation for the reaction is:

Fe(s) + Cu^{2+}(aq) → Fe^{2+}(aq) + Cu(s)

a Explain any one change that you would observe during this reaction.

b Explain which substance has been oxidised in this reaction.

SKILLS CRITICAL THINKING

c Write down the full (not ionic) equation for this reaction.

SKILLS REASONING

5 Some experiments were carried out to place the metals copper, nickel and silver in reactivity series order.

Experiment 1: A piece of copper was placed in some green nickel(II) sulfate solution. There was no change to either the copper or the solution.

Experiment 2: A coil of copper wire was suspended in some silver nitrate solution. A furry grey growth appeared on the copper wire, out of which grew spiky silvery crystals. The solution gradually turned from colourless to blue.

a Use this information to place copper, nickel and silver in reactivity series order, starting with the most reactive one.

b In another experiment, a piece of nickel was placed in some copper(II) sulfate solution.

i State one change that you would observe during this reaction.

SKILLS PROBLEM SOLVING

ii Write the full balanced equation for this reaction.

iii Write the ionic equation for this reaction and use it to explain which substance has been oxidised during the reaction.

SKILLS REASONING

6 a Look carefully at the following equations and then explain what you can say about the position of the metal X in the reactivity series.

X(s) + 2HCl(aq) → XCl_2(aq) + H_2(g)

X(s) + $CuSO_4$(aq) → XSO_4(aq) + Cu(s)

X(s) + $FeSO_4$(aq) → no reaction

SKILLS REASONING

b Decide whether X will react with the following substances. If it will react, state the names of the products, if not state 'no reaction'.

i Silver nitrate solution
ii Zinc oxide
iii Cold water
iv Copper(II) chloride solution
v Dilute sulfuric acid

SKILLS CRITICAL THINKING

7 If you add some powdered aluminium to a small amount of cold dilute hydrochloric acid in a boiling tube, very little happens. If you warm this gently, it starts to fizz very rapidly.

a State the name of the gas given off to produce the fizzing.

b If you used an excess of hydrochloric acid, the result would be a colourless solution. State the name of the solution.

SKILLS PROBLEM SOLVING

c Write the full balanced equation for the reaction.

SKILLS REASONING

d Explain why the aluminium hardly reacts at all with the dilute acid in the cold, but reacts vigorously after even gentle heating.

SKILLS EXECUTIVE FUNCTION

8 If you have some small pieces of the metal titanium and any simple apparatus that you might need, describe how you would find out the approximate position of titanium in the reactivity series, using only water and dilute hydrochloric acid. You only need to find out that the reactivity is 'similar to iron' or 'similar to magnesium', for example. Your experiments should be done in an order that guarantees maximum safety. For example, if titanium's reactivity turned out to be similar to potassium, dropping it into dilute hydrochloric acid wouldn't be a good idea!

SKILLS CRITICAL THINKING

9 In the past, cars were made from mild steel, which was then painted. In more modern cars, the mild steel is galvanised before it is painted.

a State the conditions under which iron/steel rusts.

b Explain how painting prevents iron/steel from rusting.

c What is meant by *galvanised steel*?

d Describe and explain the effect that galvanised steel has on the life of the car.

SKILLS INTERPRETATION

10 A student tested four unknown metals (the names are all imaginary) with different metal salt solutions. She put a tick (✔) if there was a reaction and a cross (✖) if there was no change. Some of her results are shown in the table.

	Pearsonium chloride solution	Mollium chloride solution	Rosium chloride solution	Amelium chloride solution
pearsonium	✖		✖	
mollium	✔	✖	✔	✔
rosium			✖	✖
amelium				✖

a Copy and complete the table.

SKILLS CRITICAL THINKING

b Arrange the metals in an order of reactivity (most reactive first).

SKILLS PROBLEM SOLVING

c Copy and complete the equation:

mollium + pearsonium chloride →

12 ACIDS AND ALKALIS

This chapter explores what indicators, acids and alkalis are. The reactions of acids are also discussed in Chapter 13.



▲ Figure 12.1 Acids range from the extremely dangerous, needing protective clothing to clean up spills . . .



▲ Figure 12.2 . . . to a natural part of our diet: oranges contain citric acid.

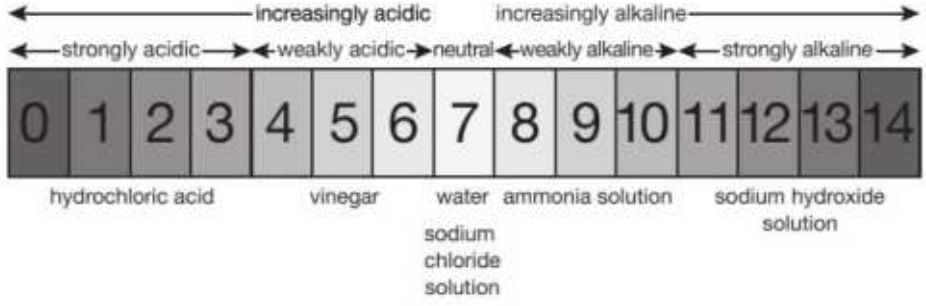
LEARNING OBJECTIVES

- Describe the use of litmus, phenolphthalein and methyl orange to distinguish between acidic and alkaline solutions
- Understand how the pH scale, from 0–14, can be used to classify solutions as strongly acidic (0–3), weakly acidic (4–6), neutral (7), weakly alkaline (8–10) and strongly alkaline (11–14)
- Describe the use of universal indicator to measure the approximate pH value of an aqueous solution
- Know that acids in aqueous solution are a source of hydrogen ions, and alkalis in an aqueous solution are a source of hydroxide ions
- Know that alkalis can neutralise acids

pH AND INDICATORS

THE pH SCALE

The **pH scale** ranges from about 0 to about 14, and tells you how acidic or how alkaline a solution is.



▲ Figure 12.3 The pH scale. **Vinegar** is a solution of ethanoic acid.

We can classify substances as strongly acidic/alkaline or weakly acidic/alkaline based on their pH. Remember, when writing pH, it is a small p and a big H (the symbol for hydrogen).

Table 12.1 We can classify solutions according to their pH

	pH	Solution
strongly acidic	0–3	hydrochloric acid
weakly acidic	4–6	ethanoic acid (vinegar)
neutral	7	sodium chloride
weakly alkaline	8–10	ammonia
strongly alkaline	11–14	sodium hydroxide

EXTENSION WORK

These are actually only approximate ranges and depend on the concentration of the acid/alkali solution. A 0.10 mol/dm^3 solution of ethanoic acid actually has a pH of 2.88.

MEASURING pH

USING UNIVERSAL INDICATOR

HINT

You can measure pH much more accurately using a pH meter.

Universal indicator is made from a mixture of **indicators**, which change colour in a gradual way over a range of pH values. It can be used as a solution or as paper. The most common form is known as *full-range* universal indicator. It changes through a variety of colours from pH 1 right up to pH 14, but it isn't very accurate.



▲ Figure 12.4 Using universal indicator solution to measure the pH of various solutions.

The colour of the paper or solution is checked against a chart to find the pH.

ACID–ALKALI INDICATORS

Any substance that has different colours depending on the pH can be used as an indicator. Some common indicators and their colours in acidic and alkaline solutions are shown in Table 12.2.

Table 12.2 The colours of various indicators in acidic and alkaline solutions

	Acid	Alkali
litmus	red	blue
methyl orange	red	yellow
phenolphthalein	colourless	pink
universal indicator	red	blue

KEY POINT

Litmus can be used as a solution or as litmus paper.

Litmus is red in acidic solutions and blue in alkaline ones. In neutral solutions, the colour is purple, which is an equal mixture of the red and blue forms. Universal indicator is green in neutral solutions.

ACIDS

Table 12.3 Some acids showing the replaceable hydrogen

Acid	Formula
hydrochloric acid	HCl
nitric acid	HNO_3
sulfuric acid	H_2SO_4
ethanoic acid	CH_3COOH
phosphoric acid	H_3PO_4

The formulae of some acids are given in Table 12.3.

All acids contain hydrogen and when acids react the hydrogen shown in red in Table 12.3 is replaced by something else; all acids have replaceable H. For example, when hydrochloric acid reacts with sodium hydroxide we obtain:

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

The H of the HCl has been replaced by an Na.

Not all of the hydrogens in acids are replaceable, for example in ethanoic acid only the H attached to the O is replaceable, not the ones joined to the C.

When acids are in water they dissociate (break apart) to form hydrogen ions (H^+), for example:

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

$$HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$$

$$H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

When we are measuring pH we are actually measuring the concentration of these H^+ ions in the solution. This is why the H in pH is written with a capital letter.

We can define acids as *substances that act as a source of hydrogen ions (H^+) in solution*.

EXTENSION WORK

At the next level, you will discover that pH is defined by a mathematical equation: $pH = -\log_{10}[H^+(aq)]$.

BASES

Bases are substances that neutralise acids by combining with the hydrogen ions in them. When we are referring to a base at this level we usually mean a metal oxide, a metal hydroxide or ammonia (NH_3).

ALKALIS



▲ Figure 12.5 Ammonia solution is sometimes called ammonium hydroxide. It is an alkali and is used in some cleaning products. Some universal indicator solution has been added to it in the beaker.

Some bases dissolve in water to form solutions containing hydroxide ions. These are alkalis.

Alkalis are a source of hydroxide (OH^-) ions in solution.

Examples of alkalis are sodium hydroxide and potassium hydroxide (all the Group 1 hydroxides). When sodium hydroxide is in water it breaks apart to form sodium and hydroxide ions:

$$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$$

The other alkali you will meet is a solution of ammonia (NH_3). The ammonia reacts with the water to form ammonium ions and hydroxide ions:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

These alkalis all have a pH greater than 7.

OTHER ALKALINE SOLUTIONS

There are some other substances, such as soluble metal carbonates, that react with water to form hydroxide ions:

$$Na_2CO_3(aq) + H_2O(l) \rightleftharpoons NaOH(aq) + NaHCO_3(aq)$$

EXTENSION WORK

The ionic equation for a carbonate reacting with water is:

$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + HCO_3^-(aq)$

There are not many soluble carbonates, but sodium carbonate and potassium carbonate are both alkalis with a pH greater than 7. This is due to the OH^- ions in the solution. Only some of the carbonate ions react with water, so these solutions are only weakly alkaline.

REACTING ACIDS WITH BASES AND ALKALIS

Acids react with bases or alkalis in a ***neutralisation reaction****.*

REACTING ACIDS WITH BASES

Metal oxides, such as copper(II) oxide and magnesium oxide, are bases.



▲ Figure 12.6 Copper(II) oxide reacts with hot dilute sulfuric acid to form blue copper(II) sulfate solution.

Copper(II) oxide reacts with hot dilute sulfuric acid, in a neutralisation reaction, to produce a solution of copper(II) sulfate and water:

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

Copper(II) oxide is an ionic compound containing the O^{2-} ion and what has happened in this reaction is that the H^+ ions from the acid have combined with the O^{2-} ions from the base to form water (H_2O).

REACTING ACIDS WITH ALKALIS

Sodium hydroxide solution (an alkali) reacts with dilute hydrochloric acid to form sodium chloride and water:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

This is a neutralisation reaction. Sodium hydroxide and sodium chloride are both ionic compounds and so will be present as ions in solution. HCl(aq) is an acid and so will dissociate into $H^+(aq)$ and $Cl^-(aq)$. We can therefore re-write this equation showing all the ions.

$$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow Na^+(aq) + Cl^-(aq) + H_2O(l)$$

The $Na^+(aq)$ and $Cl^-(aq)$ ions are the same on both sides of the equation and so are spectator ions. We can leave the spectator ions out of this equation to just show the things that have changed:

$$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$$

This is an ionic equation. All neutralisation reactions for an acid reacting with an alkali will have the same ionic equation. This is because they all involve the OH^- ions from the alkali reacting with the H^+ ions from the acid to form water.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 State the colours of methyl orange, phenolphthalein and litmus in each of the following solutions:

a sodium hydroxide solution

b hydrochloric acid solution.

SKILLS ANALYSIS

2 Table 12.4 gives the pH of some solutions. Classify each as strongly acidic, strongly alkaline, weakly acidic, weakly alkaline or neutral by copying the table and putting ticks in the appropriate boxes.

Table 12.4

Solution	pH	Strongly acidic	Weakly acidic	Neutral	Weakly alkaline	Strongly alkaline
potassium iodide	7					
propanoic acid	4.2					
sodium carbonate	9.5					
potassium hydroxide	13					
iron(III) chloride	2.4					
nitric acid	1.3					

SKILLS PROBLEM SOLVING

3 Write equations for the reactions between:

a sodium oxide and nitric acid

b potassium hydroxide and sulfuric acid.

SKILLS CRITICAL THINKING

4 Explain what type of reaction is occurring in 3.

13 ACIDS, BASES AND SALT PREPARATIONS

Acids were introduced in Chapter 12. In this chapter we will look more closely at some of the reactions of acids and how to make salts.



▲ Figure 13.1 Sodium chloride is common salt. You don't normally make it. It occurs naturally.

LEARNING OBJECTIVES

- Know the general rules for predicting the solubility of ionic compounds in water:
  - common sodium, potassium and ammonium compounds are soluble
  - all nitrates are soluble
  - common chlorides are soluble, except those of silver and lead(II)
  - common hydroxides are insoluble except for those of sodium, potassium and calcium (calcium hydroxide is slightly soluble)
- Understand acids and bases in terms of proton transfer
- Understand that an acid is a proton donor and a base is a proton acceptor
- Describe the reactions of hydrochloric acid, sulfuric acid and nitric acid with metals, bases and metal carbonates (excluding the reactions between nitric acid and metals) to form salts
- Know that metal oxides, metal hydroxides and ammonia can act as bases, and that alkalis are bases that are soluble in water
- Describe an experiment to prepare a pure, dry sample of a soluble salt, starting from an insoluble reactant
- Practical: Prepare a sample of pure, dry hydrated copper(II) sulfate crystals, starting from copper(II) oxide

SALTS

All acids contain hydrogen. When that hydrogen is replaced by a metal, the compound formed is called a **salt**. Magnesium sulfate is a salt, and so is zinc chloride, and so is potassium nitrate.

The formulae of some acids and salts are given in Table 13.1.

Table 13.1 Some acids and salts

Acid	Formula	Example of salt	Name of salts
hydrochloric acid	HCl	NaCl	chlorides
nitric acid	HNO_3	KNO_3	nitrates
sulfuric acid	H_2SO_4	$CuSO_4$	sulfates
ethanoic acid	CH_3COOH	CH_3COONa	ethanoates
phosphoric acid	H_3PO_4	K_3PO_4	phosphates

Sulfuric acid can be thought of as the **parent acid** of all the sulfates (the salts formed from sulfuric acid are all called sulfates). It doesn't matter if the replacement of the hydrogen can't be done directly. For example, you can't make copper(II) sulfate from copper and dilute sulfuric acid because they don't react. There are, however, other ways of making it from sulfuric acid – copper(II) sulfate is still a salt.

REMINDER

These salts contain the NH_4^+ ion.

Salts are also formed when the hydrogen in an acid is replaced with NH_4. These are ammonium salts, for example NH_4Cl (ammonium chloride) and $(NH_4)_2SO_4$ (ammonium sulfate).

REACTIONS OF ACIDS

Before we look at some practical methods to make salts, we need to study the reactions of acids.

REACTING ACIDS WITH METALS

KEY POINT

Of the common acids in the lab, nitric acid has much more complex reactions with metals. You won't be asked about this at International GCSE.

Simple dilute acids react with metals depending on their positions in the reactivity series.

- Metals below hydrogen in the series don't react with dilute acids.
- Metals above hydrogen in the series react to produce hydrogen gas.
- The higher the metal is in the reactivity series, the more vigorous the reaction. You would never mix metals such as sodium or potassium with acids because their reactions are too violent.

REMINDER

Remember: MASH

A summary equation for metals above hydrogen in the reactivity series:

metal + acid → salt + hydrogen

REACTIONS INVOLVING MAGNESIUM AND ACIDS

WITH DILUTE SULFURIC ACID

There is rapid fizzing and a colourless gas is evolved, which pops with a lighted splint (the test for hydrogen). The reaction mixture becomes very warm as heat is produced. The magnesium gradually disappears to leave a colourless solution of magnesium sulfate.

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

This is a displacement reaction. The more reactive magnesium has displaced the less reactive hydrogen.



▲ Figure 13.2 Magnesium reacting with dilute sulfuric acid

WITH DILUTE HYDROCHLORIC ACID

The reaction looks exactly the same. The only difference is that this time a solution of magnesium chloride is formed.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

EXTENSION WORK

Acids in solution form ions. Dilute sulfuric acid contains hydrogen ions and sulfate ions. Dilute hydrochloric acid contains hydrogen ions and chloride ions.

You can rewrite the equations above as ionic equations. In the case of sulfuric acid:

$$Mg(s) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq) + H_2(g)$$

The sulfate ion hasn't been changed by the reaction. It is a spectator ion, and so we don't include it in the ionic equation:

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

Repeating this with hydrochloric acid, we find that the chloride ions are also spectator ions:

$$Mg(s) + 2H^+(aq) + 2Cl^-(aq) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq) + H_2(g)$$

Not including the spectator ions produces the ionic equation:

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

The reactions look the same because they are the same. All solutions of acids contain hydrogen ions. That means that magnesium will react with any simple dilute acid in the same way.

REMINDER

Ionic compounds are present as separate ions in solution, so in $MgSO_4(aq)$ the $Mg^{2+}(aq)$ and $SO_4^{2-}(aq)$ ions are separated from each other.

REACTIONS INVOLVING ZINC AND ACIDS

Again, the reactions between zinc and the two acids look exactly the same. The reactions are slower because zinc is lower down the reactivity series than magnesium.

The equations are:

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

EXTENSION WORK

The ionic equations are both the same:

$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

BASES

We saw in Chapter 12 that bases are substances that neutralise acids by combining with the hydrogen ions in them to produce water. When we are referring to a base at this level, we usually mean a metal oxide, a metal hydroxide or ammonia.

REACTING ACIDS WITH BASES

Metal oxides, such as copper(II) oxide and magnesium oxide, are bases.

REACTING DILUTE SULFURIC ACID WITH COPPER(II) OXIDE

The copper(II) oxide (black powder) reacts with hot dilute sulfuric acid to produce a blue solution of copper(II) sulfate.

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

All the metal oxide and acid combinations that you will meet at International GCSE behave in exactly the same way as the reaction between copper(II) oxide and dilute sulfuric acid, that is, they produce a salt and water. Most need to be heated for the reaction to start.

Copper(II) oxide is an ionic compound containing the O^{2-} ion. What has happened in this reaction is that the H^+ ions from the acid have combined with the O^{2-} ions to form water (H_2O).

The general equation for the reaction of a metal oxide (base) with an acid is

metal oxide + acid → salt + water

This is a neutralisation reaction – the base neutralises the acid (water is formed).

BASES AND ALKALIS

Some metal oxides are soluble in water and react with it to form solutions of metal hydroxides, for example:

$$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$$

All the Group 1 oxides do this reaction, so for potassium oxide we would get:

$$K_2O(s) + H_2O(l) \rightarrow 2KOH(aq)$$

Most other metal oxides are not soluble in water.

Calcium oxide dissolves slightly to form calcium hydroxide:

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$$

Another alkali you will meet is a solution of ammonia (NH_3). The ammonia reacts with the water to form ammonium ions and hydroxide ions:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

All these solutions contain hydroxide ions. We learned in the last chapter that we can define alkalis as solutions that are a source of hydroxide (OH^-) ions, so all of these solutions are alkalis.

REACTING ACIDS WITH METAL HYDROXIDES

All metal hydroxides react with acids in a neutralisation reaction:

metal hydroxide + acid → salt + water

REACTING DILUTE HYDROCHLORIC ACID WITH SODIUM HYDROXIDE SOLUTION

Mixing sodium hydroxide solution and dilute hydrochloric acid produces a colourless solution so not much seems to have happened. But if you repeat the reaction with a thermometer in the beaker, the temperature rises several degrees, showing that there has been a chemical change. Sodium chloride solution has been formed:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

We saw in Chapter 12 that the ionic equation for this reaction is:

$$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$$

All neutralisation reactions for an acid reacting with an alkali have the same ionic equation: they all involve the hydroxide ions from the alkali reacting with the H^+ ions from the acid to form water.

REACTING ACIDS WITH CARBONATES

Carbonates react with cold dilute acids to produce carbon dioxide gas.

A summary equation for acids and carbonates:

carbonate + acid → salt + carbon dioxide + water

THE REACTION BETWEEN COPPER(II) CARBONATE AND DILUTE ACIDS

Green copper(II) carbonate reacts with the common dilute acids to give a blue or blue-green solution of copper(II) sulfate, copper(II) nitrate or copper(II) chloride. Carbon dioxide gas is given off. You can recognise this because it turns limewater milky.

All the equations have the same form:

$$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$$

$$CuCO_3(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$

$$CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + CO_2(g) + H_2O(l)$$



▲ Figure 13.3 The reaction between copper(II) carbonate and dilute sulfuric acid.

THE REACTION BETWEEN SODIUM CARBONATE AND DILUTE ACIDS

Sodium carbonate is soluble in water. The equation for the reaction of sodium carbonate with hydrochloric acid is:

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

HINT

Carbonates are not mentioned as bases on the syllabus; only metal oxides, metal hydroxides and ammonia.

EXTENSION WORK

If we show the ions (remembering that HCl splits apart into its ions in solution):

$$2Na^+(aq) + CO_3^{2-}(aq) + 2H^+(aq) + 2Cl^-(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + CO_2(g) + H_2O(l)$$

By not including the spectator ions we obtain the ionic equation:

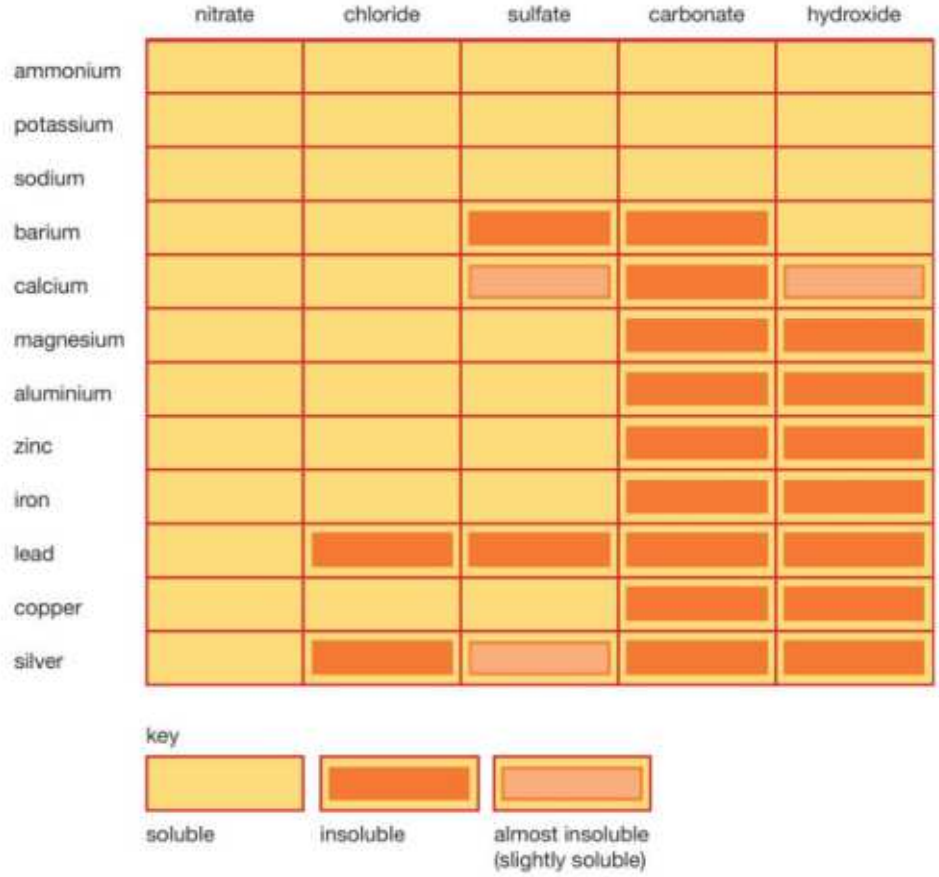
$$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$$

Because carbonate ions react by accepting hydrogen ions, we can classify carbonate ions as bases.

SALT PREPARATIONS

In the next section we will learn about a method to make soluble salts. Before we can do this, we need to know which substances are soluble and which are insoluble in water.

THE SOLUBILITY OF IONIC COMPOUNDS IN WATER



▲ Figure 13.4 Solubility patterns

NOTES ON THE TABLE

To keep the table simple, it includes one or two compounds (aluminium carbonate, for example) which don't actually exist. Don't worry about these. The problem won't arise at International GCSE.

There is no clear line between 'insoluble' and 'almost insoluble' compounds. The ones picked out as 'almost insoluble' include the more common ones that you might need to know about elsewhere in the course.

HINT

It can seem a bit frightening to have to remember all this, but it isn't as difficult as it looks at first sight.

Except for the carbonates and hydroxides, most of these compounds are soluble. Learn the exceptions in the sulfates and chlorides.

The reason for the exceptions in the carbonates and hydroxides is that all sodium, potassium and ammonium compounds are soluble.

Note that:

- all sodium, potassium and ammonium compounds are *soluble*
- all nitrates are *soluble*
- most common chlorides are *soluble*, except lead(II) chloride and silver chloride
- most common sulfates are *soluble*, except lead(II) sulfate, barium sulfate, silver sulfate and calcium sulfate
- most common carbonates are *insoluble*, except sodium, potassium and ammonium carbonates
- most metal hydroxides are *insoluble* (or *almost insoluble*), except sodium, potassium and ammonium hydroxides. Calcium hydroxide is slightly soluble in water.

MAKING SOLUBLE SALTS (EXCEPT SODIUM, POTASSIUM AND AMMONIUM SALTS)

These all involve reacting a solid with an acid. You can use any of the following mixtures:

- acid + metal (but only for the moderately reactive metals from magnesium to iron in the reactivity series)
- acid + metal oxide or hydroxide
- acid + carbonate.

Whatever mixture you use, the method is basically the same.

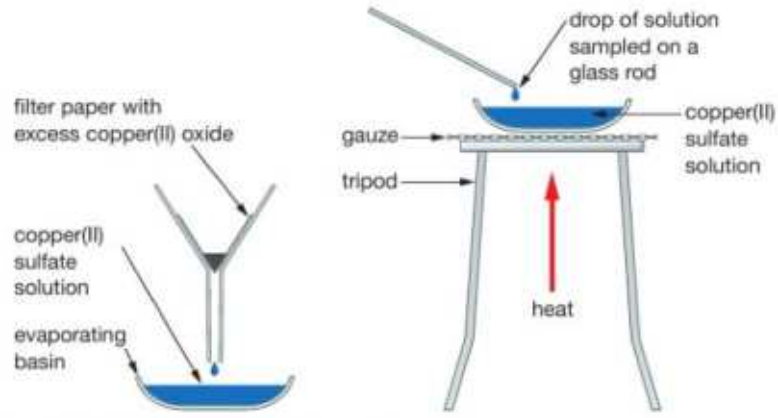
ACTIVITY 5

▼ PRACTICAL: MAKING COPPER(II) SULFATE CRYSTALS

Safety note: Direct heating of the acid is not recommended. Wear eye protection and do not evaporate the solution to dryness. The acid is best heated in a boiling tube placed in a water bath. Avoid contact with the crystals as they are harmful and irritating to both the skin and eyes.

The practical procedure for this is as follows:

- Measure 50 cm^3 of dilute sulfuric acid into a beaker and heat it on a tripod and gauze using a Bunsen burner.
- Add a spatula full of black copper(II) oxide and continue heating. If all the copper(II) oxide disappears add more copper(II) oxide until there is some left in the beaker. Stir the mixture well to make sure that no more will react. At this stage, we have added *excess* copper(II) oxide – there is more than enough to react with all the acid present. When there is copper(II) oxide left, we know that all the acid has been neutralised.
- Filter off the excess copper(II) oxide and transfer the filtrate (solution), which is blue, to an evaporating basin. The solution we have now is copper(II) sulfate.



▲ Figure 13.5 Making copper(II) sulfate crystals

The equation for the formation of the solution is:

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

- Heat the solution of copper(II) sulfate over a Bunsen burner to boil off some of the water and concentrate the solution.
- Keep heating until a saturated solution is formed. We can test this by dipping a glass rod into the solution. If crystals form on the glass rod when we remove it we know that the solution is very close to saturated and crystals will also begin to form in the solution.

EXTENSION WORK

In the method described here, you add an excess of a solid to an acid, and then filter off the unreacted solid. You do this to make sure all the acid is used up. This method does not work for making sodium, potassium and ammonium salts. The problem is that all sodium, potassium and ammonium compounds are soluble in water. The solid you added to the acid would not only react with the acid, but any excess would just dissolve in the water present. You wouldn't have any visible excess to filter off. There's no simple way of seeing when you have added just enough of the solid to neutralise the acid. A different method therefore has to be used for making sodium, potassium and ammonium salts.

- Stop heating the reaction mixture and allow it to cool slowly at room temperature so that larger crystals can form.
- Remove the blue crystals from the reaction mixture by filtration, or by just pouring off the remaining solution.
- The crystals can be dried by blotting them with a paper towel, or they can be left to dry in a warm place.

WHY NOT SIMPLY EVAPORATE THE SOLUTION TO DRYNESS?

It would seem much easier to just evaporate off all the water by boiling rather than crystallising the solution slowly, but evaporating to dryness wouldn't give you blue copper(II) sulfate crystals. Instead, you would produce a white powder of anhydrous copper(II) sulfate.

When many salts form their crystals water from the solution becomes chemically bound up with the salt. This is called *water of crystallisation*. A salt which contains water of crystallisation is said to be *hydrated*. We can show the crystallisation part of the reaction as:

$$CuSO_4(aq) + 5H_2O(l) \rightarrow CuSO_4 \cdot 5H_2O(s)$$

KEY POINT

'Anhydrous' means 'without water'.

Safety note: Wear eye protection. Heating must be very gentle to avoid 'spitting' of hot particles.



▲ Figure 13.6 Copper(II) sulfate crystals

MAKING MAGNESIUM SULFATE CRYSTALS

We can add excess magnesium to sulfuric acid. This time the acid does not have to be heated.

When we add the magnesium the reaction mixture will fizz (hydrogen is given off). We keep adding magnesium until the fizzing stops and there is magnesium left in the beaker. This means that all the acid has reacted. The equation for the formation of the solution of magnesium sulfate is:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

Again the solution is concentrated by heating it and allowed to crystallise. The crystallisation reaction is:

$$MgSO_4(aq) + 7H_2O(l) \rightarrow MgSO_4 \cdot 7H_2O(s)$$



▲ Figure 13.7 Dilute sulfuric acid with magnesium

HOW DO YOU KNOW WHETHER YOU NEED TO HEAT THE MIXTURE?

Carbonates react with dilute acids in the cold, and so does magnesium. Most other things that you are likely to come across need to be heated.



▲ Figure 13.8 Do you need to heat the mixture?

THEORIES OF ACIDS AND BASES

In Chapter 12, we met the idea that an acid is something that produces $H^+(aq)$ ions in solution and an alkali is something that produces $OH^-(aq)$ ions in solution. This is called the Arrhenius theory of acids and bases. For example, when hydrogen chloride gas is dissolved in water to form hydrochloric acid the molecules dissociate to form H^+ ions:

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

A neutralisation reaction can be shown as H^+ from an acid reacting with OH^- from an alkali to form water.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

The problem with this definition of acids and bases is that it only applies to reactions that occur in aqueous solution and is not more widely applicable.

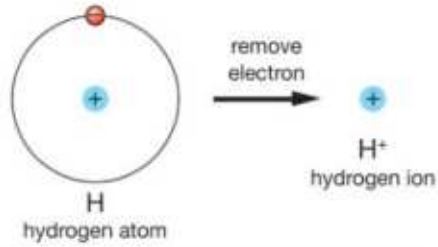
There is a more general theory of acids and bases that can be used in more situations:

- *An acid is a proton (hydrogen ion) donor.*
- *A base is a proton (hydrogen ion) acceptor.*

This is called the Brønsted–Lowry theory.

HINT

You do not have to remember the names of the theories.

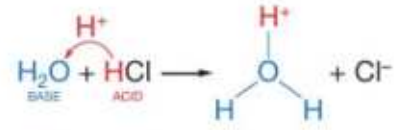


▲ Figure 13.9 A hydrogen ion (H^+) is a proton. If an electron is removed from a hydrogen atom, only a proton is left.

A better way of writing the reaction that occurs when hydrogen chloride dissolves in water is:

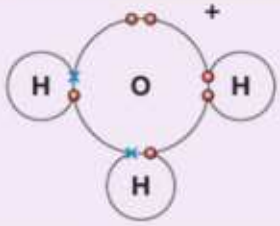
$$H_2O(l) + HCl(aq) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

The HCl donates (gives) a proton (H^+) to an H_2O molecule. So, according to our definition, the HCl is an acid and H_2O is a base because it accepts the proton.



▲ Figure 13.10 HCl donates a proton and H_2O accepts it.

EXTENSION WORK



In the dot-and-cross diagram for the H_3O^+ ion you can see that the covalent bond that formed between the H_2O and the H^+ is unusual in that both the shared electrons come from the O. This is called a dative covalent bond or a co-ordinate covalent bond. Once it has been formed, it is exactly the same as a 'normal' covalent bond.

KEY POINT

You have already met the ammonium (NH_4^+) ion, which is obtained when H^+ is added to ammonia (NH_3). The hydroxonium ion is the equivalent ion for water. You do not have to remember the name *hydroxonium ion*.

KEY POINT

To understand the reaction between ammonia and hydrochloric acid in relation to the Arrhenius theory we have to realise that ammonia reacts with water to form OH^- ions:

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

and that hydrochloric acid dissociates to form H^+ ions:

$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$

and that the overall reaction involves H^+ ions reacting with OH^- ions to form water:

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$



▲ Figure 13.12 Ammonia and hydrogen chloride gases also react to form ammonium chloride (the white smoke): $NH_3(g) + HCl(g) \rightleftharpoons NH_4^+Cl^-(s)$

The $H_3O^+(aq)$ ion is called the **hydroxonium ion**. This is the ion that we usually write simply as $H^+(aq)$. You can think of it as a hydrogen ion joined to a water molecule. Cl^- has a negative charge because the H^+ left an electron behind when it transferred to the H_2O.

THE REACTION BETWEEN NH_3 AND HCl

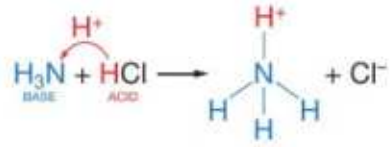
Dilute hydrochloric acid reacts with ammonia solution in a neutralisation reaction to form a salt, ammonium chloride:

$$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$$

Ammonium chloride is an ionic salt so we can show the ions that are present:

$$NH_3(aq) + HCl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$$

We can see now that, in order to form ammonium chloride, the HCl must donate a proton (H^+) to the NH_3. The HCl is an acid because it donates a proton and the NH_3 is a base because it accepts the proton.



▲ Figure 13.11 HCl is an acid and donates a proton to NH_3 (a base).

MORE ACID-BASE REACTIONS

Acids in solution are acidic because they donate a proton (H^+) to water to form the hydroxonium ion. If we take a general acid (HA), this is what happens when it is put into water:

$$HA(aq) + H_2O(l) \rightarrow H_3O^+(aq) + A^-(aq)$$

HA donates a proton to H_2O, which acts as a base. For nitric acid this would be:

$$\underset{\text{acid}}{HNO_3(aq)} + \underset{\text{base}}{H_2O(l)} \rightarrow H_3O^+(aq) + NO_3^-(aq)$$

When bases, such as metal oxides (e.g. Na_2O), react with water they accept a proton from water, for example:

$$(Na^+)_2O^{2-}(s) + H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq)$$

The O^{2-} ion accepts a proton from the water. In this reaction the water acts as an acid because it donates a proton.

When sulfuric acid reacts with copper(II) oxide (CuO) we have:

$$Cu^{2+}O^{2-}(s) + H_2SO_4(aq) \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l)$$

H_2SO_4 is an acid, it donates protons to CuO, the base.

Ammonia is also a base:

$$\underset{\text{base}}{NH_3(aq)} + \underset{\text{acid}}{H_2O(l)} \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

The ammonia accepts a proton (H^+) from the water.

For reactions such as:

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

HINT

Water can act as proton acceptor (base) or proton donor (acid) in reactions on this page. Do not get confused with what is happening here; remember, water is still neutral! We are simply understanding the reactions that occur in terms of proton transfer.

What actually happens is that the H_3O^+ ion formed when the acid reacts with water donates a proton to the base, OH^-.

$$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$$
acid base

But for International GCSE purposes, we almost always use the simplified version:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 State which of the following will react with dilute sulfuric acid:

a copper, copper(II) oxide, copper(II) hydroxide, copper(II) carbonate

SKILLS PROBLEM SOLVING

b In the case of each of the substances which does react, write the equation (including state symbols) for the reaction. All of these substances are insoluble solids.

SKILLS CRITICAL THINKING

2 Read this description of the chemistry of metal **A** and some of its compounds, and then answer the questions.

Metal **A** has no reaction with dilute hydrochloric acid or dilute sulfuric acid. It forms a black oxide, **B**, which reacts with hot dilute sulfuric acid to give a blue solution, **C**. Metal **A** also forms a green compound, **D**, which reacts with dilute nitric acid to give a colourless gas, **E**, and another blue solution, **F**. The colourless gas, **E**, turned limewater milky.

a State the names of **A**, **B**, **C**, **D**, **E** and **F**.

SKILLS PROBLEM SOLVING

b Write equations for the reactions between:

i **B** and dilute sulfuric acid

ii **D** and dilute nitric acid.

SKILLS CRITICAL THINKING

3 a Nickel, Ni, is a silvery metal just above hydrogen in the reactivity series. Nickel(II) compounds in solution are green.

i Describe what you would see if you warmed some nickel with dilute sulfuric acid in a test-tube.

ii State the name of any gas formed.

SKILLS PROBLEM SOLVING

iii Write the equation for the reaction between nickel and dilute sulfuric acid.

b Nickel(II) carbonate is a green, insoluble powder. A spatula measure of nickel(II) carbonate is added to some dilute hydrochloric acid in a test-tube.

SKILLS CRITICAL THINKING

i Describe what you would observe in this experiment.

SKILLS PROBLEM SOLVING

ii Write an equation for the reaction that occurs.

SKILLS CRITICAL THINKING

4 Organise the following compounds into two lists: those that are soluble in water and those that are insoluble.

sodium chloride, lead(II) sulfate, zinc nitrate, calcium carbonate, iron(III) sulfate, lead(II) chloride, potassium sulfate, copper(II) carbonate, silver chloride, aluminium nitrate, barium sulfate, ammonium chloride, magnesium nitrate, calcium sulfate, sodium phosphate, nickel(II) carbonate, chromium(III) hydroxide, potassium dichromate(VI)

SKILLS EXECUTIVE FUNCTION

SKILLS PROBLEM SOLVING

SKILLS REASONING

5 a Describe in detail the preparation of a pure, dry sample of copper(II) sulfate crystals, $CuSO_4 \cdot 5H_2O$, starting from copper(II) oxide.

b Write equations for i the reaction producing copper(II) sulfate solution and ii the crystallisation reaction.

6 All of the following equations represent acid–base reactions. For each of the equations, state which substance is the acid and which the base.

a $CO_3^{2-}(s) + H_3O^+(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$

b $MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$

c $HNO_3(aq) + NH_3(aq) \rightarrow NH_4^+(aq) + NO_3^-(aq)$

d $H_2SO_4(aq) + H_2O(l) \rightarrow HSO_4^-(aq) + H_3O^+(aq)$

e $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

f $CH_3COOH(aq) + NH_3(aq) \rightarrow CH_3COO^-(aq) + NH_4^+(aq)$

14 CHEMICAL TESTS

In this chapter we will look at how to identify substances using chemical tests.



▲ Figure 14.1 Although the reactions we learn here are useful for identifying substances in the lab and we are also introduced to some interesting chemistry, analysis of substances is now routinely carried out using sophisticated machines.

LEARNING OBJECTIVES

- Describe tests for these gases:
  - hydrogen
  - oxygen
  - carbon dioxide
  - ammonia
  - chlorine
- Describe how to carry out a flame test
- Know the colours formed in flame tests for these cations:
  - Li^+ (red)
  - Na^+ (yellow)
  - K^+ (lilac)
  - Ca^{2+} (orange-red)
  - Cu^{2+} (blue-green)
- Describe tests for these cations:
  - NH_4^+ using sodium hydroxide solution and identifying the gas evolved
  - Cu^{2+}, Fe^{2+} and Fe^{3+} using sodium hydroxide solution
- Describe tests for these anions:
  - Cl^-, Br^- and I^- using acidified silver nitrate solution
  - SO_4^{2-} using acidified barium chloride solution
  - CO_3^{2-} using hydrochloric acid and identifying the gas evolved
- Describe a test for the presence of water using anhydrous copper(II) sulfate
- Describe a physical test to show whether or not a sample of water is pure

TESTING FOR GASES

HYDROGEN, H_2

THE TEST FOR HYDROGEN GAS

A lighted splint is held to the mouth of the tube. The hydrogen explodes with a squeaky pop.

The hydrogen combines explosively with oxygen in the air to make water.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

OXYGEN, O_2

THE TEST FOR OXYGEN GAS

A glowing splint is put into the tube containing the gas. Oxygen relights a glowing splint.

CARBON DIOXIDE, CO_2

THE TEST FOR CARBON DIOXIDE GAS

The carbon dioxide is bubbled through limewater. Carbon dioxide turns limewater milky/chalky/cloudy.

Limewater is calcium hydroxide solution. Carbon dioxide reacts with it to form a white **precipitate** of calcium carbonate.

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

KEY POINT

If you keep bubbling the carbon dioxide through the limewater, the white precipitate will eventually disappear again. This is because the CO_2 reacts with the calcium carbonate to form calcium hydrogencarbonate, which is soluble in water:

$CaCO_3(s) + H_2O(l) + CO_2(g) \rightarrow Ca(HCO_3)_2(aq)$

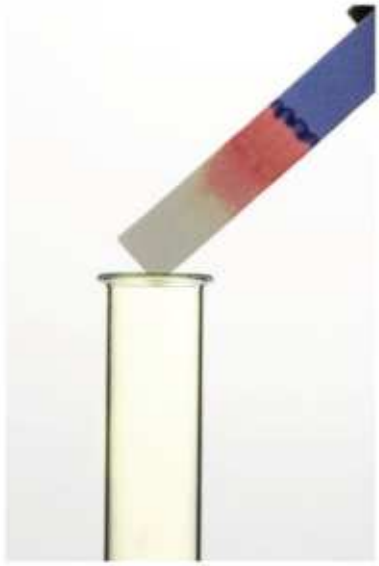
CHLORINE, Cl_2

THE TEST FOR CHLORINE GAS

A piece of damp litmus paper or universal indicator paper is put into the test-tube or held over its mouth. Chlorine is a green gas that bleaches (turns white) the damp litmus paper or universal indicator paper.

If blue litmus paper or universal indicator paper are used for this test, they go red first (the chlorine dissolves in the water to form an acidic solution) and then white.

Safety note: Wear eye protection. Avoid inhaling or 'sniffing' chlorine or ammonia, especially if you have a breathing problem such as asthma.



▶ Figure 14.2 Chlorine bleaches damp litmus paper.

AMMONIA, NH_3

THE TEST FOR AMMONIA GAS

Hold a piece of damp universal indicator paper or red litmus paper at the mouth of the test-tube. Ammonia turns the universal indicator paper/litmus paper blue.

Ammonia is the only alkaline gas that you will meet at International GCSE.

TESTING FOR WATER

USING ANHYDROUS COPPER(II) SULFATE

Water turns white anhydrous copper(II) sulfate blue.

Anhydrous copper(II) sulfate lacks water of crystallisation and is white. Dropping water onto it replaces the water of crystallisation and turns it blue.

anhydrous copper sulfate + water → hydrated copper sulfate

$CuSO_4(s)$ + $5H_2O(l)$ → $CuSO_4 \cdot 5H_2O(s)$

white blue

If you aren't sure about water of crystallisation, see Chapter 13.

This test works for anything that contains water, so would work with sodium chloride solution or sulfuric acid. It does *not* show that the water is pure.

Safety note: Avid skin contact with the copper salts.



▲ Figure 14.3 Testing for water with anhydrous copper(II) sulfate.

PHYSICAL TEST TO SHOW THAT WATER IS PURE

You can find out whether a sample of water is pure by measuring the freezing (melting) point or boiling point. Pure water freezes at exactly 0 °C and boils at exactly 100 °C at 1 atmosphere pressure. If the water is impure, it will usually freeze at a lower temperature and boil at a higher temperature.

TESTING FOR IONS

All salts contain at least one cation (positive ion) and anion (negative ion). In this section we will learn how to test for these anions and cations. We do the tests for these anions and cations separately.

FLAME TESTS

A flame test is used to show the presence of certain metal ions (cations) in a compound. A platinum or nichrome wire is dipped into concentrated hydrochloric acid and then into the salt you want to test, so that some salt sticks on the end. The wire and the salt are then held just within a non-luminous (roaring) Bunsen burner flame and the colour observed.

KEY POINT

If a new piece of wire is not being used, it is usually cleaned by dipping it into concentrated hydrochloric acid and then holding it in a non-luminous Bunsen flame. This is repeated until the wire doesn't give any colour to the flame.

HINT

The colour for sodium is described as yellow in the specification, but you will also see it described as orange. Both are usually acceptable.

KEY POINT

Lithium isn't the only ion to give a red flame colour. Strontium gives a very similar colour. The only way to be sure is to compare the flame colour next to the flame colour of a known compound of lithium or strontium.

Safety note: Wear eye protection and take great care with the concentrated acid. Do not get it on your skin and watch out for 'spitting' when heating it on the wire.



▲ Figure 14.4 Red shows lithium ions.



▲ Figure 14.5 Yellow shows the presence of sodium ions.



▲ Figure 14.6 Lilac shows potassium ions.



▲ Figure 14.7 Orange-red shows calcium ions.



▲ Figure 14.8 Blue-green shows the presence of copper(II) ions.

TESTING FOR CATIONS (POSITIVE IONS) USING SODIUM HYDROXIDE SOLUTION

Of the common hydroxides, only sodium, potassium and ammonium hydroxides dissolve in water to any extent. Most metal hydroxides are insoluble. That means that if you add sodium hydroxide solution to a solution containing the metal ions, you will get a precipitate of the metal hydroxide.

To carry out this test, you dissolve the salt in distilled (pure) water and put about 1 cm^3 in a test-tube. Add about the same volume of dilute sodium hydroxide solution. What you are looking for in most of these tests is the formation of a precipitate; the solution will go cloudy as a solid forms.

THE TEST FOR COPPER(II) IONS

HINT

Ionic equations, which just show the things that actually react, can be a useful way of showing what is happening in a precipitation reaction.

Formation of a blue precipitate shows the presence of copper(II) ions. The precipitate is copper(II) hydroxide.

$$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$$

Any copper(II) salt in solution will react with sodium hydroxide solution in this way. For example, with copper(II) sulfate solution, the full equation is:

$$CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$$



▲ Figure 14.9 The blue precipitate of copper(II) hydroxide.

THE TEST FOR IRON(III) IONS

Safety note: Wear eye protection for all these tests and avoid skin contact with the reactants and products.

Formation of an orange-brown precipitate shows the presence of iron(III) ions (Fe^{3+}). The precipitate is iron(III) hydroxide.

$$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$$

Any iron(III) compound in solution will give this precipitate. An example of a full equation might be:

$$FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$$

Notice how much more complicated the full equations for these reactions are. They also hide what is going on. Use ionic equations for **precipitation reactions** wherever possible.



▲ Figure 14.10 The orange-brown precipitate of iron(III) hydroxide.

THE TEST FOR IRON(II) IONS

KEY POINT

The green precipitate darkens on standing and turns orange-brown around the top of the tube. This is due to the iron(II) hydroxide being oxidised to iron(III) hydroxide by the air.

KEY POINT

You must carry out these three tests on a solution of the salt you are testing. If you tested the solid you would not be able to see whether a precipitate had been formed because there is already solid present.

Formation of a green precipitate shows the presence of iron(II) ions (Fe^{2+}). The precipitate is iron(II) hydroxide.

$$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$$

This could be the result of reacting, say, iron(II) sulfate solution with sodium hydroxide solution.

$$FeSO_4(aq) + 2NaOH(aq) \rightarrow Fe(OH)_2(s) + Na_2SO_4(aq)$$

Safety note: Wear eye protection for all these tests and avoid skin contact with the reactants and products.



▲ Figure 14.11 The green precipitate of iron(II) hydroxide.

THE TEST FOR AMMONIUM IONS

KEY POINT

Recognising gases by smelling them has to be done with great care. In this case, there is usually so little ammonia gas present in the cold that it is safe to smell if you take the normal precautions. You shouldn't, however, make any attempt to smell the mixture when it is warm.
Safety note: Do not attempt to smell the ammonia gas if you have a breathing problem such as asthma.

This test shows the presence of an ammonium salt. Sodium hydroxide solution reacts with ammonium salts (either solid or in solution) to produce ammonia gas. In the cold, there is just enough ammonia gas produced for you to be able to smell it. If you warm it, you can test the gas coming off with a piece of damp red litmus paper or universal indicator paper. Ammonia is alkaline and turns the litmus paper/universal indicator blue. The ionic equation is:

$$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$$

This test works on a sample of a solid or a solution as you are not looking for a precipitate.

A full equation for adding sodium hydroxide solution to solid ammonium chloride is:

$$NH_4Cl(s) + NaOH(aq) \rightarrow NaCl(aq) + NH_3(g) + H_2O(l)$$

Table 14.1 A summary of the reactions of positive ions with sodium hydroxide solution

Ion	Result of adding NaOH(aq)	Name of precipitate formed	Formula of precipitate
Cu^{2+}	blue precipitate	copper(II) hydroxide	$Cu(OH)_2$
Fe^{2+}	green precipitate	iron(II) hydroxide	$Fe(OH)_2$
Fe^{3+}	orange-brown precipitate	iron(III) hydroxide	$Fe(OH)_3$
NH_4^+	ammonia gas produced	no precipitate	

TESTING FOR CARBONATES (CO_3^{2-})

EXTENSION WORK

The ionic equation shows any carbonate reacting with any acid.

$CO_3^{2-}(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$

Add a little dilute hydrochloric acid to your sample of salt and look for fizzing/bubbles of gas. Fizzing indicates that a gas is given off. You can test the gas by bubbling it through limewater to show that it is carbon dioxide.

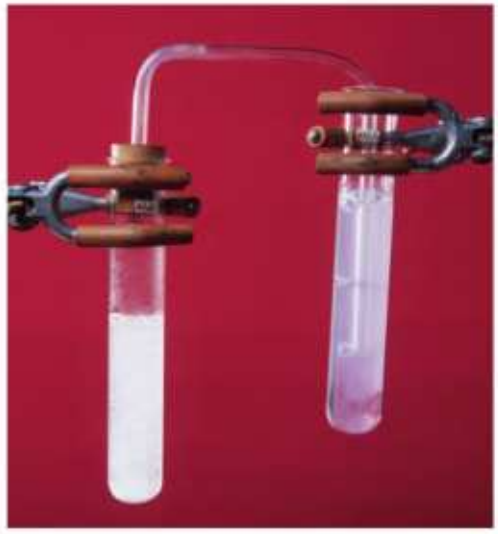
Most carbonates are insoluble in water and so you will usually be doing this test on a sample of a solid. Soluble carbonates are sodium carbonate, potassium carbonate and ammonium carbonate, and the test also works on solutions of these.

HINT

You can use any acid to do this test, but you have to be careful, especially with sulfuric acid, as some acid–carbonate combinations can produce an insoluble salt that coats the solid carbonate and stops the reaction. The test works well with dilute hydrochloric acid or dilute nitric acid.

For example, using zinc carbonate and dilute nitric acid:

$$ZnCO_3(s) + 2HNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + CO_2(g) + H_2O(l)$$



▲ Figure 14.12 We can test to see if carbon dioxide is produced by bubbling the gas through limewater (in the tube on the right) and looking to see whether the limewater goes cloudy/milky (white precipitate of calcium carbonate formed).

Safety note: Wear eye protection for all these tests and avoid skin contact with the reactants and products.

TESTING FOR SULFATES (SO_4^{2-})

KEY POINT

You could also use nitric acid and barium nitrate solution in the same way.

Make a solution of your suspected sulfate in distilled (pure) water, add some *dilute hydrochloric acid* and then add some *barium chloride solution*. A sulfate will produce a white precipitate of barium sulfate.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

You add acid to the solution to react with and remove other anions which might also produce white precipitates when you add the barium chloride solution. For example, if you didn't add acid, you would also obtain a white precipitate if there were carbonate ions present. This is because barium carbonate is also white and insoluble. The acid reacts with the carbonate ions and removes them. It is important to remember that the acid must be added *before* the barium chloride solution.

You must never acidify the solution with sulfuric acid because sulfuric acid contains sulfate ions. If you add those, you are bound to get a precipitate of barium sulfate because you have added sulfate ions.

TESTING FOR CHLORIDES (Cl^-), BROMIDES (Br^-) AND IODIDES (I^-)

Make a solution of your suspected chloride, bromide or iodide and add enough *dilute nitric acid* to make it acidic. Then add some *silver nitrate solution*.

Safety note: Wear eye protection for all these tests and avoid skin contact with the reactants and products.

A *white* precipitate (of silver chloride) shows the presence of chloride ions:

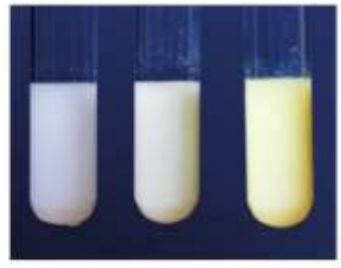
$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

A *cream* precipitate (of silver bromide) shows the presence of bromide ions:

$$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$$

A *yellow* precipitate (of silver iodide) shows the presence of iodide ions:

$$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$$



▲ Figure 14.13 Precipitates of silver chloride, silver bromide and silver iodide

KEY POINT

All of these precipitates tend to discolour to greys and pale purples on exposure to light.

KEY POINT

The 1– ions formed by the halogens (Group 7) are collectively called *halide ions*. Chloride, bromide and iodide ions are all halide ions.

The acid is added to react with and remove other anions which might also produce precipitates with silver nitrate solution, for example carbonate and hydroxide ions. You must not use hydrochloric acid (or hydrobromic acid or hydroiodic acid) as you will be adding halide ions and you are certain to obtain a precipitate.

Table 14.2 A summary of the tests for negative ions (anions)

Ion	Test	Positive result	Product of reaction
CO_3^{2-}	add dilute hydrochloric acid then bubble any gas produced through limewater	fizzing, limewater goes cloudy (white precipitate)	CO_2 $CaCO_3$ (with limewater)
SO_4^{2-}	add dilute hydrochloric acid followed by barium chloride solution	white precipitate	$BaSO_4$
Cl^-	add dilute nitric acid followed by silver nitrate solution	white precipitate	AgCl
Br^-	add dilute nitric acid followed by silver nitrate solution	cream precipitate	AgBr
I^-	add dilute nitric acid followed by silver nitrate solution	yellow precipitate	AgI

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 Name the gas being described in each of the following cases.

a A green gas that bleaches damp litmus paper.

b A gas that dissolves readily in water to produce a solution with a pH of about 11.

c A gas that produces a white precipitate with limewater.

d A gas that pops when a lighted splint is placed in it.

e A gas that relights a glowing splint.

SKILLS EXECUTIVE FUNCTION

2 Describe in detail how you would carry out the following tests. In each case state whether you would carry out the test on the solid or a solution, and describe what you would expect to see happen.

a A flame test for lithium ions in lithium chloride.

b A test for ammonium ions in ammonium sulfate.

c A test for sulfate ions in ammonium sulfate.

d A test for carbonate ions in calcium carbonate.

e A test for iodide ions in potassium iodide.

3 **A** is an orange solid, which dissolves in water to give an orange solution. When sodium hydroxide solution is added to a solution of **A**, an orange-brown precipitate, **B**, is formed. Adding dilute nitric acid and silver nitrate solution to a solution of **A** gives a white precipitate, **C**.

SKILLS CRITICAL THINKING

a State the names of **A**, **B** and **C**.

SKILLS PROBLEM SOLVING

b Write equations (full or ionic) for the reactions producing **B** and **C**.

SKILLS PROBLEM SOLVING, CRITICAL THINKING

4 **D** is a green crystalline solid that dissolves in water to give a very pale green solution. Addition of sodium hydroxide solution to a solution of **D** produces a green precipitate, **E**, which turns orange-brown around the top after standing in air. Addition of dilute hydrochloric acid and barium chloride solution to a solution of **D** gives a white precipitate, **F**.

a State the names of **D**, **E** and **F**.

SKILLS PROBLEM SOLVING

b Write equations (full or ionic) for the reactions producing **E** and **F**.

5 **G** is a colourless crystalline solid which reacts with dilute nitric acid to give a colourless solution, **H**, and a colourless, odourless gas, **I**, which turns limewater milky. **G** has a lilac flame colour.

SKILLS CRITICAL THINKING

a State the names of **G**, **H** and **I**.

SKILLS PROBLEM SOLVING

b Write an equation (full or ionic) for the reaction between **G** and dilute nitric acid.

6 **J** is a colourless solid. When it is warmed with sodium hydroxide solution it produces a gas, **K**, which turns damp universal indicator paper blue. When nitric acid, followed by silver nitrate solution, is added to a solution of **J**, a cream precipitate of **L** is formed.

SKILLS CRITICAL THINKING

a State the names of **J**, **K** and **L**.

SKILLS PROBLEM SOLVING

b Write an ionic equation for the formation of the cream precipitate.

SKILLS EXECUTVE FUNCTION

7 A student has found that her sample of potassium nitrate is contaminated with small amounts of a green solid. She picks out a small piece of the green solid and finds that it is insoluble in water.

SKILLS CRITICAL THINKING

a Describe how you would make a pure sample of potassium nitrate from the impure mixture.

b The student believes that the green solid could be copper(II) carbonate. Describe a series of tests that the student could use to confirm this.

8 A student finds a bottle containing a colourless liquid in the laboratory.

a Describe a test to show that the bottle contains water.

b Describe a test to show whether it is pure water.

SKILLS EXECUTIVE FUNCTION, REASONING

c The student carried out the test in b and it showed that the water was not pure. He then carried out some more tests to try to identify the solution. The following results were obtained:

Test	Result
add sodium hydroxide solution	no visible reaction but the test-tube became warm
add dilute hydrochloric acid	no reaction
add dilute hydrochloric acid followed by barium chloride solution	no reaction
add nitric acid followed by silver nitrate solution	white precipitate

Explain what could be present in the bottle and how the student could confirm this.

UNIT QUESTIONS

You may need to refer to the Periodic Table on page 708.

SKILLS REASONING 8 marks

1 Lithium, sodium and potassium are three elements in Group 1 of the Periodic Table. All these elements are stored under oil so that they cannot react with air and water.

a Explain in terms of the structure of the atoms why these three elements are all placed in Group 1 of the Periodic Table. **(1)**

SKILLS CRITICAL THINKING 5 marks

b State the name of the product obtained when potassium reacts with air. **(1)**

c Only three of the statements about the reaction of lithium with water given below are true. Put a cross next to each of the correct statements. **(3)**

The water turns blue	
The piece of lithium floats	
The lithium burns with a lilac flame	
Hydrogen gas is formed	
The lithium explodes	
The final solution is alkaline	
Lithium reacts more violently than sodium	

d Some data about the physical properties of lithium, sodium and potassium are shown in the table.

	Melting point / °C	Boiling point / °C	Density / g /cm^3
Li	181	1342	0.53
Na	98	883	0.97
K	63	760	0.86

Caesium is another element in Group 1 of the Periodic Table.

7 marks

i Which of the following are likely to be properties of caesium? Put crosses in two boxes. **(2)**

It forms a 1+ ion in compounds	
It has a melting point of 60 °C	
It is a non-metal	
It reacts with water and air	
It is an alkali	

SKILLS REASONING 8 marks

ii Explain why the data in the table cannot be used to predict whether caesium has a higher or lower density than potassium. **(2)**

(Total 9 marks)

SKILLS REASONING 6th **2**

A student carried out some reactions between solutions of chlorine, bromine and iodine, and solutions of potassium halides. Some of their results are shown in the table:

	Potassium chloride solution	Potassium bromide solution	Potassium iodide solution
Chlorine solution		orange solution formed	
Bromine solution			
Iodine solution	no reaction	no reaction	

a Explain why the student did not carry out the experiments shaded in dark grey in the table. **(2)**

SKILLS INTERPRETATION

b Complete the table. **(3)**

SKILLS PROBLEM SOLVING 7th

c Write a word equation for the reaction between chlorine and potassium bromide. **(1)**

8th

d Complete and balance the ionic equation for the reaction between chlorine and potassium bromide solutions: **(3)**

$Cl_2(aq) + Br^-(aq) \rightarrow$

SKILLS REASONING 9th

e Explain in terms of electrons why the reaction between chlorine and potassium bromide solution is described as a redox reaction. **(3)**

f Chlorine can be prepared in the laboratory by the reaction between concentrated hydrochloric acid and potassium manganate(VII). The equation for the reaction is:

$2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl_2 + 8H_2O + ...Cl_2$

SKILLS PROBLEM SOLVING 8th

i The equation is not balanced. Give the number that should be put in front of Cl_2 in order to balance it. **(1)**

SKILLS EXECUTIVE FUNCTION 5th

ii Describe a test for chlorine gas. **(2)**

Test:

Positive result:

iii When chlorine dissolves in water some chloride ions are formed. Describe a chemical test to show that a solution contains chloride ions. **(3)**

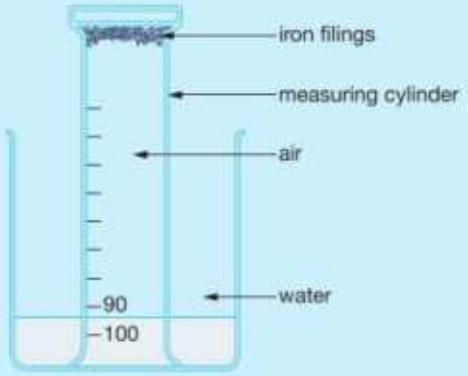
Test:

Positive result: **(Total 18 marks)**

SKILLS CRITICAL THINKING 5th

3 a State the name of the most common gas in the air. **(1)**

b A student carries out an experiment to measure the percentage of oxygen in the air. He used the following apparatus:



He carried out the following procedure:

- Put some damp iron filings at the bottom of a 100 cm^3 measuring cylinder.
- Invert the measuring cylinder in a beaker of water.
- Take the initial reading of the level of water in the measuring cylinder.
- Take a reading of the level of water in the measuring cylinder every day for 1 week.

The student's results were:

initial reading on measuring cylinder / cm^3	94
reading on measuring cylinder after 1 day / cm^3	85
reading on measuring cylinder after 2 days / cm^3	80
reading on measuring cylinder after 3 days / cm^3	77
reading on measuring cylinder after 4 days / cm^3	76
reading on measuring cylinder after 5 days / cm^3	75
reading on measuring cylinder after 6 days / cm^3	75
reading on measuring cylinder after 7 days / cm^3	75

SKILLS REASONING

i Explain why the water level rises. **(2)**

6th

ii Explain why the reading on the measuring cylinder eventually remains constant. **(1)**

SKILLS CRITICAL THINKING

iii Give the name of the iron compound that is formed in this experiment. **(1)**

SKILLS REASONING

iv The student trapped the gas in the tube and put a lighted splint into it. Explain why the splint goes out. **(2)**

SKILLS PROBLEM SOLVING

v Using the results in the table, calculate the percentage oxygen present in the air in the measuring cylinder after 1 day. **(4)**

SKILLS CRITICAL THINKING 7th

vi The student decided that 1 week is too long to wait for results so suggested using a more reactive metal such as calcium or lithium in this experiment. Explain one reason, other than that it might be too dangerous, why the experiment will not work with these metals. **(2)**

SKILLS EXECUTIVE FUNCTION 5th

vii Suggest one change that the student could make to the experiment so he does not have to wait so long for the results. **(1)**

c Sulfur reacts with oxygen. A teacher burns a piece of sulfur in a gas jar of oxygen.

SKILLS CRITICAL THINKING 5

i State the colour of the flame. **(1)**

SKILLS PROBLEM SOLVING 9

ii Write a balanced equation for the reaction that occurs. **(1)**

SKILLS REASONING 6

iii A few drops of litmus solution are put into the gas jar at the end of the experiment. State and explain what colour will be seen. **(2)**

d Sodium reacts with oxygen to form sodium oxide.

SKILLS PROBLEM SOLVING 9

i Write a chemical equation for this reaction. **(2)**

SKILLS CRITICAL THINKING 5

ii When sodium oxide reacts with water an alkaline solution is formed. State the name of the ion responsible for making the solution alkaline. **(1)**

(Total 21 marks)

SKILLS DECISION MAKING 6

4 This question is about copper(II) sulfate solution.

a Describe a procedure to make a solution of copper(II) sulfate starting from copper(II) oxide. **(3)**

5

b Describe a chemical test that can be used to show that the solution contains sulfate ions. **(2)**

SKILLS CRITICAL THINKING

c A student added some sodium hydroxide solution to the copper(II) sulfate solution. State the name of the blue precipitate formed. **(1)**

d A student carried out an experiment to investigate displacement reactions of three different metals with copper(II) sulfate solution. She followed this method:

- Put some copper(II) sulfate solution into a polystyrene cup.
- Measure the initial temperature.
- Add some metal.
- Stir the solution.
- Record the maximum temperature.

SKILLS EXECUTIVE FUNCTION

i The student uses the same amount in moles of each metal in the experiments. State two other variables the student should keep the same in this experiment to allow her to be able to compare the different metals. **(2)**

SKILLS ANALYSIS 6

ii The student recorded the following data.

Metal	Temperature change / °C
zinc	15
silver	0
nickel	7

Arrange the four metals, zinc, silver, copper and nickel, in order of reactivity, starting with the most reactive. **(1)**

SKILLS REASONING 7

iii The student did not carry out the experiment with copper and copper(II) sulfate. Predict, giving a reason, what the temperature rise would be for this experiment. **(2)**

8

iv The student carried out the experiment using 3.25 g of zinc (0.05 mol). She then used the same amount in moles of nickel and silver. Another student decided to use the same mass (3.25 g) of each metal. The results of the two students were very similar. Suggest reasons for this. **(3)**

SKILLS PROBLEM SOLVING

v The ionic equation for the reaction between copper(II) sulfate solution and nickel is:

$$Ni(s) + Cu^{2+}(aq) \rightarrow Ni^{2+}(aq) + Cu(s)$$

Use the ionic equation to explain whether nickel is oxidised or reduced in this reaction. **(2)**

SKILLS EXECUTIVE FUNCTION

e The student wants to make some anhydrous copper(II) sulfate. Describe how she could do this starting with copper(II) sulfate solution. **(2)**

f The student carried out a flame test on the anhydrous copper(II) sulfate.

SKILLS CRITICAL THINKING

i Describe how to carry out a flame test. **(2)**

ii State the colour of the flame produced when the student carried out a flame test on copper(II) sulfate. **(1)**

(Total 21 marks)

SKILLS INTERPRETATION

5 This question is about hydrogen chloride and hydrochloric acid.

a Hydrochloric acid is made when hydrogen chloride dissolves in water. Draw a dot-and-cross diagram for hydrogen chloride. **(2)**

SKILLS CRITICAL THINKING

b When hydrogen chloride dissolves in water an acid–base reaction occurs. The equation for this reaction is:

$$HCl(aq) + H_2O(l) \rightarrow Cl^-(aq) + H_3O^+(aq)$$

Explain why this is classified as an acid–base reaction and identify the acid and the base. **(3)**

c A student wants to show that an unknown solution she has been given contains chloride ions. She puts a small amount of the solution in a test-tube and adds dilute nitric acid followed by silver nitrate solution.

i Describe what would be seen if the solution contains chloride ions. **(1)**

ii Explain why hydrochloric acid cannot be added instead of nitric acid. **(2)**

SKILLS PROBLEM SOLVING

d Write an equation, including state symbols, for the reaction that occurs when hydrochloric acid is added to solid copper(II) carbonate. **(3)**

(Total 11 marks)

SKILLS CRITICAL THINKING 5th **6**

This question is about chemical tests.

Samples of a very pale green solution, **X**, were tested as follows:

Test	Observation
A sample of **X** was acidified with dilute nitric acid and silver nitrate solution was added	A white precipitate (**A**) was formed
A small amount of sodium hydroxide solution was added to a sample of solution **X**	A dark green precipitate (**B**) was formed
Chlorine was bubbled through a sample of **X**	The pale green solution turned yellow (solution **C**)
A small amount of sodium hydroxide solution was added to solution **C**	An orange-brown precipitate (**D**) was formed

a Use the results from the first two tests to identify **X**. **(2)**

6th b State the name and formula of **B**. **(2)**

c State the name and formula of **D**. **(2)**

7th d Explain what type of reaction occurred when chlorine was bubbled through **X**. **(2)**

(Total 8 marks)

CHEMISTRY UNIT 3 PHYSICAL CHEMISTRY

In a world where the population has more than trebled in the last 100 years, fighting against hunger is an extremely important challenge. At the beginning of the 20th century scientists developed industrial processes to make artificial fertilisers that can be used to increase crop yields. In order to develop these processes, chemists and chemical engineers from around the world have had to understand the principles of energy changes, rates of reaction and reversibility. The world's resources are limited and it is vital that these processes are as efficient and environmentally friendly as possible. This is also the work of scientists.



15 ENERGETICS

Some chemical reactions produce heat. Others need to be heated constantly to make them occur at all. This chapter explores some examples of both kinds of reaction and examines how energy changes during reactions can be measured by experiments.

LEARNING OBJECTIVES

- Know that chemical reactions in which heat energy is given out are described as exothermic, and those in which heat energy is taken in are described as endothermic
- Describe simple calorimetry experiments for reactions such as combustion, displacement, dissolving and neutralisation
- Calculate the heat energy change from a measured temperature change using the expression $Q = mc\Delta T$
- Calculate the molar enthalpy change (ΔH) from the heat energy change, Q
- Practical: Investigate the temperature changes accompanying some of the following types of change:
  - salts dissolving in water
  - neutralisation reactions
  - displacement reactions
  - combustion reactions

EXOTHERMIC REACTIONS

Some chemical reactions give out energy in the form of heat. A reaction that *gives out heat to the surroundings* is said to be **exothermic**. If you are holding a test-tube in which an exothermic reaction is occurring, you will notice that the test-tube *gets warmer*.

An example of an exothermic reaction is adding water to calcium oxide. If you add water to solid calcium oxide, the heat produced is enough to boil the water and produce steam. Calcium hydroxide is produced.

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$$

In an *exothermic* reaction, *the products of the reaction have less (chemical) energy than the reactants*. In the reaction, *chemical energy* (stored in the bonds of chemicals) *is converted to heat energy*, which is released to the surroundings. The temperature of the reaction mixture and its surroundings *goes up*.

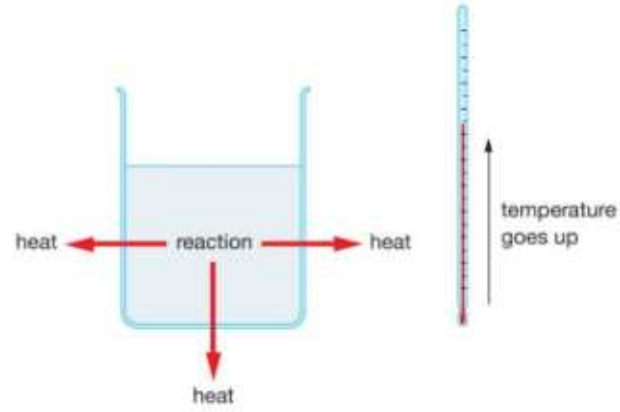
DID YOU KNOW?

Calcium oxide is known as **quicklime**. Adding water to it is described as *slaking* it. The calcium hydroxide produced is known as **slaked lime**.

Safety note: It is less hazardous to use a lump of calcium oxide, rather than powered calcium oxide



▲ Figure 15.1 Calcium oxide reacting with water.



▲ Figure 15.2 In an exothermic reaction, chemical energy is converted to heat energy. Heat is released so the temperature goes up.

You will come across lots of exothermic reactions in this course. Some examples are given below.

COMBUSTION REACTIONS



▲ Figure 15.3 The burning of hydrogen is used in oxy-hydrogen cutting equipment underwater.

Any reaction that produces a flame is exothermic. Burning things produces heat energy.

For instance, hydrogen burns in oxygen, producing water and lots of heat:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

Apart from burning, other exothermic changes include:

- the reactions of metals with acids
- neutralisation reactions
- displacement reactions.

THE REACTIONS OF METALS WITH ACIDS

REMINDER

This reaction is described in detail in Chapter 11 (pages 373–374).

When magnesium reacts with dilute sulfuric acid, for example, the mixture gets very warm:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

NEUTRALISATION REACTIONS

REMINDER

You can read about this reaction in Chapter 12 (page 384). We will investigate how much heat energy is released in a typical neutralisation reaction later in this chapter (pages 423–425).

About the only interesting thing that you can observe happening when sodium hydroxide solution reacts with dilute hydrochloric acid is that the temperature rises:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

DISPLACEMENT REACTIONS

The thermite reaction between powdered aluminium and iron(III) oxide is a displacement (competition) reaction. This reaction releases a large amount of heat, which can be used in railway welding:

$$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(l) + Al_2O_3(s)$$

ENTHALPY CHANGE OF A REACTION

KEY POINT

ΔH is pronounced 'delta H'. The Greek letter Δ is used to mean 'change in'. ΔH means 'change in heat'. Note: it is not possible to measure how much enthalpy (H) something has – you can only measure the change in enthalpy (ΔH) when it reacts.

REMINDER

The mole is a unit for the amount of a substance. You can read more about it in Chapter 5.

KEY POINT

The units for ΔH can be written as kJ/mol or kJ mol^{-1}.

You can measure the amount of heat energy taken in or released in a chemical reaction. It is called the **enthalpy change** of the reaction and is given the symbol ΔH. The enthalpy change is *the amount of heat energy taken in or given out in a chemical reaction*. It is the difference between the energy of the products and the energy of the reactants.

ΔH is given a minus or a plus sign to show whether heat is being given out or absorbed by the reaction. You always look at it from the point of view of the reactants. For an exothermic reaction, ΔH is given a *negative* number because the reactants are *losing* energy as heat. That heat is transferred to the surroundings, which then get warmer. ΔH is measured in units of kJ/mol (kilojoules per mole).

In an equation, the amount of heat given out or taken in can be shown as, for example:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g) \quad \Delta H = -466.9\,kJ/mol$$

The ΔH written next to an equation represents the enthalpy change of the reaction, i.e. 466.9 kJ of heat is given out when *one mole* of magnesium reacts in this way. You know heat has been given out because ΔH has a negative sign.

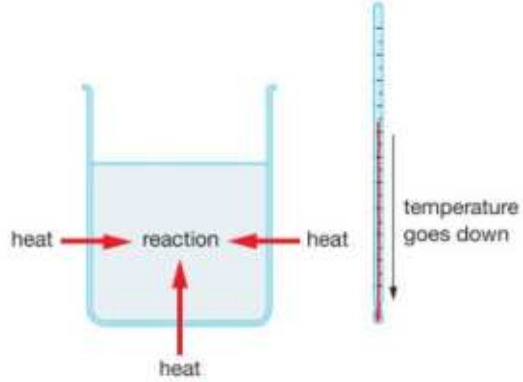
ENDOTHERMIC REACTIONS

A reaction that absorbs heat from the surroundings is said to be **endothermic**. If you hold a test-tube in which an endothermic reaction is occurring you will notice that it *gets colder*.



◀ Figure 15.4 A boy using a cold pack to relieve pain in his elbow. Endothermic reactions occur in the chemical cold pack to absorb heat from the surroundings and reduce the temperature of his arm.

In an endothermic reaction, *the products have more (chemical) energy than the reactants*. In order to supply the extra energy that is needed to convert the reactants (lower energy) into the products (higher energy), heat energy needs to be absorbed from the surroundings. This *heat energy is converted to chemical energy* (energy stored in the bonds of chemicals). The temperature of the reaction mixture and the surroundings *goes down* because heat energy has been converted into a different form of energy.



▲ Figure 15.5 In an endothermic reaction, heat energy is converted to chemical energy. Heat is absorbed so the temperature goes down.

You have seen the *thermal decomposition* of metal carbonates before in Chapter 10. These are examples of endothermic reactions. You have to heat a carbonate constantly to make it decompose.

REMINDER

Not all reactions that have to be heated are endothermic reactions. Sometimes we just heat something to make it go faster.

For example, copper(II) carbonate (green) decomposes on heating to produce copper(II) oxide (black).

$$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$$

Similarly, zinc carbonate decomposes to form zinc oxide when heated.

$$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$$

MEASURING ENTHALPY CHANGES OF REACTIONS

Here we discuss how we can measure how much heat is taken in or given out by a chemical reaction, in other words the enthalpy change of a reaction.

SPECIFIC HEAT CAPACITY

KEY POINT

The unit for specific heat capacity is J/g/°C or J g^{-1} $°C^{-1}$.

When we heat something up, it gets hotter. The **specific heat capacity** tells us about *how much* energy has to be put in to increase the temperature of something. The specific heat capacity of a substance is defined as *the amount of heat needed to raise the temperature of 1 gram of a substance by 1 °C*.

For water, the value is 4.18 J/g/°C (joules per gram per degree Celsius). This means that 4.18 J of heat energy is needed if we want to increase the temperature of 1 g of water by 1 °C. If you want the temperature of 1 g of water to go up by 2 °C, then 4.18 × 2 = 8.36 J of heat energy must be supplied. If now you have 2 g of water, then 2 × 8.36 J of energy would be needed to raise the temperature by 2 °C.

KEY POINT

Again, we are using the delta (Δ) symbol to indicate a change, but this time a temperature change.
The concept of specific heat capacity also applies to the cooling of a substance. For example, to cool 1 g of water by 1 °C we need to take out 4.18 J of energy.

The amount of heat energy required is *directly proportional* to the mass (m) and the temperature change (ΔT) of the substance. The following equation can be used to calculate how much heat energy needs to be supplied to raise the temperature of mass m by ΔT °C:

$$\text{heat energy change} = \text{mass} \times \text{specific heat capacity} \times \text{temperature change}$$

$$Q = m \times c \times \Delta T$$

CALORIMETRY EXPERIMENTS FOR DETERMINING THE ENTHALPY CHANGES OF REACTIONS

It is fairly uncomplicated to measure the amount of heat absorbed or given out in several kinds of chemical reactions and physical changes. The technique used to do this is called **calorimetry** and it is based on the idea that if we use the heat from a reaction to heat another substance, such as water, we can then use the equation introduced above ($Q = mc\Delta T$) to calculate the amount of heat released. Here the mass, the specific heat capacity and the temperature change are all referring to *the substance heated*. If we know how many moles of reactants are used in the reaction, we can then work out the **molar enthalpy change**, ΔH, of the reaction in the unit kJ/mol.

The following activity illustrates how we can use calorimetry to determine the molar enthalpy change of combustion of an alcohol, i.e. how much heat energy is released when 1 mole of alcohol burns.

Safety note: Wear eye protection. Do not carry a lit spirit burner and do not fill or re-fill one when there is a naked flame nearby.

KEY POINT

A *calorimeter* is simply something that we do a calorimetry experiment in; here it is a copper can, in other experiments it can be a polystyrene cup.

KEY POINT

You may see other versions of this experiment recommending a different temperature rise or suggesting that you heat the water for a fixed number of minutes. There's no ideal answer to this. The higher the temperature the water reaches, the greater the heat losses during the experiment. On the other hand, if you just increase the temperature of the water by a small amount, errors in reading the thermometer or in finding the mass change of the alcohol become too significant.

ACTIVITY 1

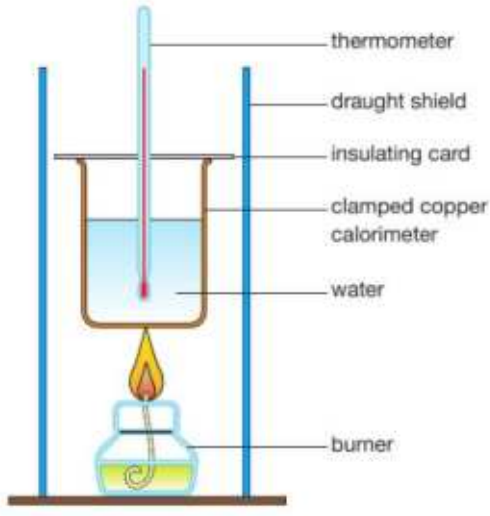
▼ PRACTICAL: MEASURING ENTHALPY CHANGES IN COMBUSTION REACTIONS

One of the most common calorimetry experiments at International GCSE is to measure the amount of heat given off when a number of small **alcohols** are burned. You could use methanol, ethanol, propan-1-ol and butan-1-ol.

The alcohols are burned in a small spirit burner, and the heat produced is used to heat some water in a copper can (the calorimeter).

The following procedure could be used:

- Measure 100 cm^3 of cold water using a measuring cylinder and transfer the water to a copper can.
- Take the initial temperature of the water.
- Weigh a spirit-burner containing ethanol with its lid *on*. The lid should be kept on when the **wick** is not lit to prevent the alcohol from evaporating.
- Arrange the apparatus as shown in Figure 15.6 so that the spirit-burner can be used to heat the water in the copper can. The apparatus is shielded as far as possible to prevent draughts.
- Light the wick to heat the water. Stop heating when you have a reasonable temperature rise of water (say, about 40.0 °C). The flame can be extinguished by putting the lid back on the wick.
- Stir the water thoroughly and measure the maximum temperature of the water.
- Weigh the spirit-burner again with its lid *on*.
- The experiment can be repeated with the same alcohol to check for reliability, and then carried out again with whatever other alcohols are available.



▲ Figure 15.6 A calorimetry experiment to measure the enthalpy change of combustion of alcohols.

SAMPLE DATA

volume of water / cm^3	100
mass of burner + ethanol before experiment / g	137.36
mass of burner + ethanol after experiment / g	136.58
original temperature of water / °C	21.5
final temperature of water / °C	62.8

Combustion is an exothermic reaction so the temperature of the water goes up. As ethanol is burned, the total mass of the burner and ethanol goes down.

Using the above data we can determine how much heat is released when one mole of an alcohol is burned, that is, the molar enthalpy change of combustion.

CALCULATIONS FOR ACTIVITY 1

We are going to use the equation $Q = mc\Delta T$ so we need to find out what each quantity is.

Temperature change of water = $\Delta T = 62.8 - 21.5 = 41.3\,°C$.

Mass of water being heated = $m = 100\,g$, the density of water is approximately $1\,g/cm^3$ at room temperature, so $100\,cm^3$ of water has a mass of 100 g.

c is the specific heat capacity of the water (it is the water that is being heated): $c = 4.18\,J/g/°C$

Heat gained by water = $Q = mc\Delta T = 100 \times 4.18 \times 41.3 = 17\,260\,J$.

Divide Q by 1000 to give energy in kJ = 17.26 kJ.

KEY POINT

The enthalpy change when 1 mole of a substance is burned is called the *enthalpy change of combustion*.

This means 17.26 kJ of heat energy is released by the combustion of the ethanol in this experiment. To calculate the amount of heat produced when 1 mole of ethanol, CH_3CH_2OH, burns, you need to find out how many moles of ethanol are burned in your experiment.

Mass of ethanol burned = decrease in the mass of the burner
= 137.36 − 136.58 = 0.78 g

HINT

We have quoted the final answer to *3 significant figures*. In the exam, it is usually best to quote answers to 3 significant figures. When we are doing experiments we should actually base our answers on *the piece of data with the fewest significant figures*. When you are doing calculations carry more significant figures through on your calculator and then round the value at the end.

Ethanol has the formula C_2H_5OH. We can calculate the relative molecular mass of ethanol by adding up the relative atomic masses:
$(2 \times 12) + (5 \times 1) + 16 + 1 = 46$

Number of moles (n) of ethanol, CH_3CH_2OH, burned

$$n = \frac{\text{mass } (m)}{\text{relative molecular mass } (M_r)} = \frac{0.78}{46} = 0.01696\,\text{mol}$$

Molar enthalpy change of combustion of ethanol (ΔH)

$$\Delta H = \frac{\text{heat energy change } (Q)}{\text{number of moles of ethanol burned } (n)}$$

$$= \frac{17.26}{0.01696} = 1020\,\text{kJ/mol}$$

HINT

Always remember to put in the sign of the enthalpy change at this stage. You will be able to see whether the reaction is endothermic (ΔH +) or exothermic (ΔH −) from looking at the original temperature change: does it go up (exothermic) or down (endothermic)?

The amount of heat released in the **complete combustion** of 1 mole of ethanol is therefore:

$$CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O \qquad \Delta H = -1020\ \text{kJ/mol}$$

The negative sign shows that heat is released and the combustion reaction is exothermic.

EVALUATION OF THE EXPERIMENTAL RESULTS

How accurate is the figure of –1020 kJ/mol for the enthalpy change of the combustion of ethanol? The accepted value found in data booklets for ethanol is –1370 kJ/mol, which means that 1370 kJ of heat should be given out when 1 mole of ethanol burns. You can see that the value we obtained is less exothermic than expected; our reaction seemed to give out less heat than expected.

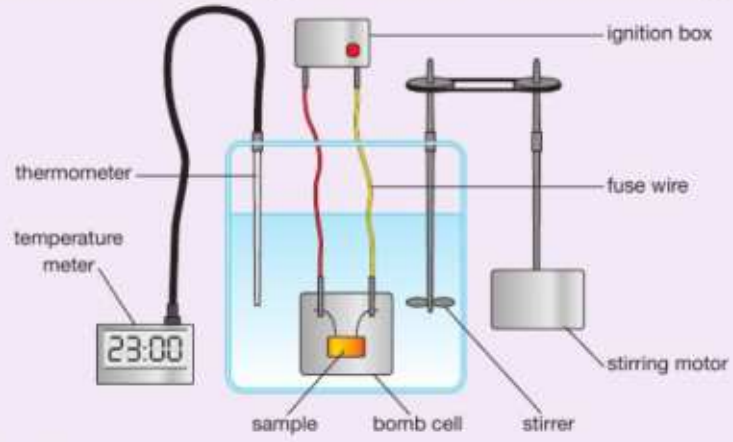
There are many sources of error in this experiment, in particular *large amounts of heat loss*.

The warm water gives out heat to the air, heat is lost from the flame, which goes straight into the air rather than into the water, and heat is used to raise the temperature of the copper can and the thermometer.

Another major source of error is the *incomplete combustion* of alcohol. We will talk about incomplete combustion in more detail in Chapter 18. Incomplete combustion of an alcohol occurs when there is not enough oxygen present. Incomplete combustion releases less heat than complete combustion. We can see that the combustion in Activity 1 is incomplete because the flame of the wick is often yellow orange rather than blue, and **soot** (carbon) is produced at the bottom of the copper can. If the combustion is complete, the flame should be blue and carbon dioxide should be produced instead of carbon.

EXTENSION WORK

A bomb calorimeter can be used to obtain more accurate values of the enthalpy changes of combustion. The substance to be combusted is ignited electrically and burns in the presence of pure oxygen. The heat transferred to both water and the calorimeter itself is determined to give a more accurate value of the enthalpy change.



▲ Figure 15.7 Bomb calorimeter

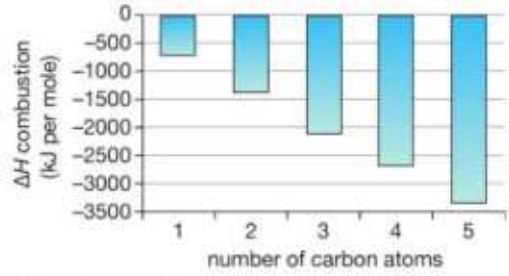
That doesn't mean you can't use this experiment to make useful comparisons. If you repeat it with other alcohols, under conditions that are as similar as possible, you can find how the heat evolved (given out) changes as the alcohol gets bigger.

In Figure 15.8 we can see that the combustion reaction gets more exothermic as the alcohol chain becomes longer. In other words, longer alcohols give out more heat energy per mole when they burn than shorter ones.

The increase in the heat evolved as alcohol chain lengthens is regular. The difference between one alcohol and the next is always an extra CH_2, and so the number of extra bonds broken and made (see below) increases in a regular way. That means that the heat evolved will also increase in a regular way.

KEY POINT

You may sometimes see these plotted as smooth graphs, but that is technically wrong. A smooth curve should only be used for a continuous independent variable, one which can take any value. There is no such thing as an alcohol with 0.5 or 1.64 carbon atoms! The number of carbon atoms is a **non-continuous variable** because it can only take whole number values.



▲ Figure 15.8 Molar enthalpy change of the combustion of alcohols.

WORKING OUT ENTHALPY CHANGES FOR REACTIONS INVOLVING SOLUTIONS USING CALORIMETRY EXPERIMENTS

You can use very similar methods for measuring molar enthalpy changes in displacement reactions (e.g. zinc and copper(II) sulfate solution), dissolving (e.g. dissolving ammonium chloride in water to form a solution) and neutralisation reactions (e.g. between potassium hydroxide solution and dilute hydrochloric acid). These experiments also involve heating water, but this time the water is part of the solutions we are using. We will look at how to do this in the next few practicals.

ACTIVITY 2

▼ PRACTICAL: MEASURING ENTHALPY CHANGES FOR DISPLACEMENT REACTIONS

Safety note: Avoid skin contact with the chemicals.

In order to determine the enthalpy change of the reaction of zinc and copper(II) sulfate, the following procedure could be used:

- Place a polystyrene cup in a 250 cm^3 glass beaker.
- Transfer 50 cm^3 of 0.200 mol/dm^3 copper(II) sulfate solution into the polystyrene cup using a measuring cylinder.
- Weigh 1.20 g of zinc using a weighing boat on a balance.
- Record the initial temperature of the copper(II) sulfate solution.
- Add the zinc.
- Stir the solution as quickly as possible.
- Record the maximum temperature reached.



▲ 15.9 A calorimetry experiment to measure the enthalpy change of a displacement reaction.

SAMPLE DATA

initial temperature of copper(II) sulfate solution / °C	17.0
maximum temperature of the reaction mixture / °C	27.3

We can use this data to calculate the enthalpy change for this displacement reaction, when 1 mole of copper(II) sulfate reacts with zinc.

CALCULATIONS FOR ACTIVITY 2

Heat given out in this reaction: $Q = mc\Delta T = 50 \times 4.18 \times (27.3 - 17.0)$

$= 2152.7\,J$

$= 2.1527\,kJ$

Here we assume the following:

1. The density of the copper sulfate solution is the same as that of water, so $1\,cm^3$ of solution has a mass of 1 g.
2. The specific heat capacity of the mixture is the same as that of water. This is a fairly reasonable assumption because the reaction mixture is mostly water.

In this experiment we have used excess zinc. *Excess* means more than enough zinc is present to ensure all the copper(II) sulfate reacts. If you calculate the number of moles of copper(II) sulfate and the number of moles of zinc used in this procedure, you should spot that the number of moles of zinc used is more than that of copper(II) sulfate:

$$\text{number of moles } (n) \text{ of zinc added} = \frac{\text{mass } (m)}{\text{relative atomic mass } (A_r)}$$

$$= \frac{1.20}{65}$$

$$= 0.0185\,\text{mol}$$

$$\text{number of moles } (n) \text{ of copper(II) sulfate added} = \text{volume } (V) \times \text{concentration } (C)$$

$$= 0.050 \times 0.200$$

$$= 0.0100\ \text{mol}$$

Now we need to calculate how much heat is released when 1 mole of copper sulfate reacts with excess zinc:

Molar enthalpy change of reaction (ΔH)

$$\Delta H = \frac{\text{heat energy change } (Q)}{\text{number of moles of copper sulfate reacted } (n)}$$

$$= \frac{2.1527}{0.0100} = 215\,\text{kJ/mol}$$

The amount of heat released in the displacement reaction when 1 mole of $CuSO_4$ reacts with excess Zn is therefore:

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s) \qquad \Delta H = -215\,\text{kJ/mol}$$

We have added the negative sign because we know that the temperature of the reaction mixture went up. The negative sign shows that this is an exothermic reaction; heat is released.

KEY POINT

1 mol of Zn reacts with 1 mol of $CuSO_4$, therefore 0.0100 mol of $CuSO_4$ reacts with 0.0100 mol of Zn. We added 0.0185 mol of Zn, so Zn is in excess.

REMINDER

Remember that we have to divide the volume by 1000 to convert it to dm^3 because the concentration is given in mol/dm^3.

EXTENSION WORK

You could repeat this experiment with metals of different reactivities. The more reactive a metal is, the more heat should be released in the displacement reaction. Make sure you keep everything else the same: the number of moles of the metals, the size of the solid particles, and the volume and concentration of the copper(II) sulfate solution. Do not use metals that are more reactive than magnesium, otherwise you are measuring the heat released when the metal reacts with water instead!

Safety note: Wear eye protection and avoid skin contact with the salts and their solutions.

ACTIVITY 3

▼ PRACTICAL: MEASURING ENTHALPY CHANGES WHEN SALTS DISSOLVE IN WATER

We can also use calorimetry experiments to work out the amount of heat given out/taken in when salts dissolve in water. The following procedure could be used:

- Place a polystyrene cup in a 250 cm^3 glass beaker.
- Transfer 100 cm^3 of water into the polystyrene cup using a measuring cylinder.
- Record the initial temperature of the water.
- Weigh 5.20 g of ammonium chloride using a weighing boat on a balance.
- Add the ammonium chloride to water and stir the solution vigorously until all the ammonium chloride has dissolved.
- Record the minimum temperature.

The set-up is very similar to the one used in Activity 2, see Figure 15.9.

SAMPLE DATA

initial temperature of water / °C	18.3
minimum temperature of salt solution / °C	15.1

Note: the temperature of the water decreases, so the reaction is endothermic and heat is absorbed from the surroundings for the dissolving process to occur.

We can use this data to calculate the molar enthalpy change for dissolving ammonium chloride.

CALCULATIONS FOR ACTIVITY 3

Heat absorbed: $Q = mc\Delta T = 100 \times 4.18 \times (18.3 - 15.1) = 1337.6\,J = 1.3376\,kJ$

Here we assume the following:

1. The specific heat capacity of the diluted solution of ammonium chloride is the same as that of water. This is quite a reasonable assumption because the mixture is mostly water.
2. The mass of the solution is 100 g. The mass of the ammonium chloride is relatively small and it is ignored in the calculation. There are other major sources of error in the experiment, for example heat absorbed from the surrounding air, which makes much more difference to the results.

Now we need to calculate how much heat is absorbed when 1 mole of ammonium chloride dissolves in excess water.

The relative formula mass of ammonium chloride (NH_4Cl) is $14 + 4 \times 1 + 35.5 = 53.5$.

Number of moles (n) of ammonium chloride dissolved

$$n = \frac{\text{mass } (m)}{\text{relative formula mass } (M_r)} = \frac{5.20}{53.5} = 0.0972\,\text{mol}$$

Molar enthalpy change of solution (ΔH)

$$\Delta H = \frac{\text{heat energy change } (Q)}{\text{number of moles of ammonium chloride dissolved } (n)}$$

$$= \frac{1.3376}{0.0972}$$

$$= 13.8\,\text{kJ/mol}$$

KEY POINT

Dissolving is a physical process rather than a chemical reaction. When some salts dissolve in water heat is given out (exothermic), but when others dissolve the process is endothermic.

The amount of heat absorbed when dissolving 1 mole of ammonium chloride in water is therefore:

$NH_4Cl(s) \rightarrow NH_4Cl(aq) \quad \Delta H = +13.8\,\text{kJ/mol}$

The positive sign shows that heat is absorbed and the dissolving of ammonium chloride in water is an endothermic process (the temperature goes down).

ACTIVITY 4

▼ PRACTICAL: MEASURING ENTHALPY CHANGES OF NEUTRALISATION BETWEEN AN ALKALI AND AN ACID

Safety note: Wear eye protection and avoid skin contact with the acid and alkali.

The reaction between an alkali and an acid is essentially between OH^- and H^+ ions to form water (see Chapter 12):

$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$

Let's look at the reaction between potassium hydroxide (an alkali) and hydrochloric acid. Suppose you know the concentration of the potassium hydroxide but are not so sure of the concentration of the dilute hydrochloric acid solution (the label has gone missing!). The following method could be used to find out the concentration of the acid and how much heat is released during the neutralisation reaction.

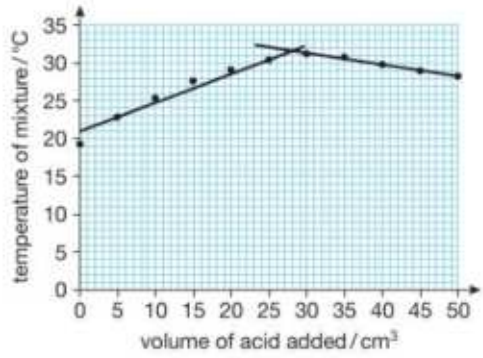
- Place a polystyrene cup in a 250 cm^3 glass beaker.
- Transfer 25 cm^3 of 2.00 mol/dm^3 potassium hydroxide into the polystyrene cup using a measuring cylinder.
- Record the initial temperature.
- Fill a burette with 50.00 cm^3 of dilute hydrochloric acid.
- Use the burette to add 5.00 cm^3 of dilute hydrochloric acid to the potassium hydroxide.
- Stir vigorously and record the maximum temperature reached.
- Continue adding further 5.00 cm^3 portions of dilute hydrochloric acid to the cup, stirring and recording the maximum temperature each time, until a total volume of 50.00 cm^3 has been added.

We can plot a graph of the temperature of the mixture versus the volume of acid added.

SAMPLE DATA

In this reaction the temperature increases at first but then decreases. The reaction between the acid and the alkali is exothermic. At the beginning the temperature goes up because the acid reacts with the alkali, giving out heat. But when all the alkali has been used up, we are just adding cold acid to our warm solution (there is no reaction because there is nothing for the acid to react with) and the temperature goes down.

Two lines of best fit can be drawn on our graph. The point where the lines cross represents complete neutralisation. From the graph, we can identify the maximum temperature reached during the experiment as 31.8 °C. At this point, 28.00 cm^3 of acid has been used.



▲ Figure 15.10 Temperature change in the neutralisation reaction between KOH and HCl.

CALCULATIONS FOR ACTIVITY 4

To work out how much heat is released in the neutralisation reaction, we can use the same calculation as before.

The total volume of the solution at the neutralisation point is 25 + 28 = 53 cm^3.

Heat given out is shown by $Q = mc\Delta T = 53 \times 4.18 \times (31.8 - 19.3) = 2769.3$ J.

If we divide by 1000 we get 2.7693 kJ.

Here we assume the following:

1. The density of the reaction mixture is the same as that of water, so 1 cm^3 of solution has a mass of 1 g.
2. The specific heat capacity of the mixture is the same as that of water. This is a fairly reasonable assumption because the neutralised solution is mostly water.

Now we need to calculate how much heat is released when 1 mole of potassium hydroxide reacts with 1 mole of hydrochloric acid:

Number of moles of KOH (n) = concentration (C) × volume (V)

$$= 2.00 \times \frac{25}{1000} = 0.0500 \text{ mol}$$

The number of moles of HCl will be exactly the same because we have taken the temperature at the neutralisation point.

Molar enthalpy change of neutralisation (ΔH)

$$\Delta H = \frac{\text{heat energy change } (Q)}{\text{number of moles of KOH or HCl reacted } (n)}$$

$$= \frac{2.7693}{0.0500} = 55.4 \text{ kJ/mol}$$

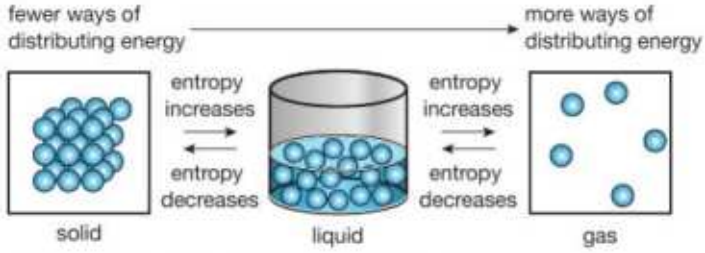
The amount of heat released in the neutralisation reaction when 1 mole of KOH reacts with 1 mole of HCl is therefore:

$$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l) \qquad \Delta H = -55.4 \text{ kJ/mol}$$

The negative sign shows that heat is released in this exothermic neutralisation reaction.

LOOKING AHEAD – ENTROPY

Many reactions we meet at International GSCE level are exothermic, for example combustion and neutralisation. Despite requiring a small amount of energy to get the reactions started (*activation energy*), these reactions release heat energy overall because the products are more stable than the reactants. This shows that enthalpy is certainly a driving force for a reaction to occur. However, endothermic processes do occur. How do they happen? Dissolving ammonium nitrate into water causes the temperature of the solution to decrease, but it dissolves anyway. This is possible because of a different factor called entropy. *Entropy is a measure of the number of ways for the energy in a system to be distributed*. It is greater in a more disordered system because the energy can be dispersed more flexibly. It follows that solids have lower entropy than liquids, which have lower entropy than gases, as shown in Figure 15.11.



▲ Figure 15.11 Entropy is greater in a more disordered system.

If the entropy of a system increases during a reaction, it is more likely for that reaction to occur. When dissolving ammonium nitrate in water, although the process is endothermic, the NH_4^+ and NO_3^- ion particles in the giant ionic lattice become separated from each other. The ions have more freedom of movement in water and the entropy of the system increases, which outweighs the effect of enthalpy.

The reaction between baking soda and vinegar is another example of an endothermic reaction that occurs spontaneously. The reaction produces a gas which leads to an increase in the entropy of the system.



▲ Figure 15.12 The reaction between baking soda and vinegar is used to make papier mâché volcanos.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING, PROBLEM SOLVING

1 Explain what is meant by an *exothermic reaction* and write balanced chemical equations for any two exothermic changes.

SKILLS REASONING

2 Explain what is meant by an *endothermic reaction*.

SKILLS CRITICAL THINKING

3 Identify each of the following changes as exothermic or endothermic. In some cases you will have to rely on your previous knowledge of chemistry. Several reactions are likely to be completely new to you.

a The reaction between sodium and water.

b Burning methane (major constituent of natural gas).

c The reaction between sodium carbonate and ethanoic acid. A thermometer placed in the reaction mixture shows a temperature drop.

d $S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta H = -297\,kJ/mol$

e $CuSO_4(s) \rightarrow CuO(s) + SO_3(g)$ $\Delta H = +220\,kJ/mol$

f If you dissolve solid sodium hydroxide in water, the solution becomes very hot.

SKILLS INTRAPERSONAL

4 Self-heating cans are used to provide warm food in situations where it is inconvenient to use a more conventional form of heat. By doing an internet (or other) search, find out how self-heating cans work. Write a short explanation of your findings (not exceeding 200 words). You should include equation(s) for any reaction(s) involved, and a diagram or picture if it is useful.

SKILLS EXECUTIVE FUNCTION

5 A student investigated the amount of heat given out when hexane, C_6H_{14}, burns using the apparatus in Figure 15.6. Hexane is a highly flammable liquid which is one of the components of petrol (gasoline).

In each case, the student calculated the amount of heat evolved per mole of hexane. Her first two experiments produced answers of –3200 and –3900 kJ/mol of heat evolved. She then decided to do a third experiment. Her results were as follows:

volume of water in copper calorimeter / cm^3	100
mass of burner + hexane before experiment / g	35.62
mass of burner + hexane after experiment / g	35.23
original temperature of water / °C	19.0
final temperature of water / °C	55.0

a Suggest a reason why the student decided to do a third experiment.

b Apart from wearing eye protection, suggest two other safety precautions the student should take during the experiment.

SKILLS PROBLEM SOLVING

c Use the results table to calculate the amount of heat in **kJ** evolved by the burning hexane during the experiment.

(Specific heat capacity of water = 4.18 J/g/°C; density of water = 1 g/cm^3.)

d Calculate the amount of heat energy released per gram of hexane.

SKILLS PROBLEM SOLVING

e Calculate the molar enthalpy change of combustion of hexane. (A_r: H = 1, C = 12)

SKILLS REASONING

f To calculate the average value of the heat evolved per mole when hexane burns, the student took an average of her results. She decided not to use the figure of –3900 in calculating the average because it was so different from the other two. Suggest two reasons why this reaction might have been more exothermic than the others.

g A data book gave a figure of –4194 kJ of heat evolved when 1 mole of hexane burns. Suggest two reasons why all the results in the student's experiment were less negative than this.

SKILLS PROBLEM SOLVING

6 When 5.15 g of lithium chloride (LiCl) is dissolved in 50 cm^3 of water the temperature of the solution goes from 17.0 °C to 33.5 °C.

a Calculate the heat energy released in this experiment. (Specific heat capacity of water = 4.18 J/g/°C; mass of 1 cm^3 of solution = 1 g.)

b Calculate the amount, in moles, of lithium chloride dissolved in the solution.

c Using your answers from a and b, calculate the enthalpy change when 1 mol of lithium chloride dissolves in water in kJ/mol.

SKILLS REASONING

d A data book gives a figure of –37.2 kJ/mol for heat released when 1 mole of lithium chloride is dissolved in water. Suggest two reasons why the value you calculated in c might be different from the value given in the data book.

16 RATES OF REACTION AND REVERSIBLE REACTIONS

Reactions can vary in speed between those that happen within fractions of a second – explosions, for example – and those that never happen at all. Gold can be exposed to the air for thousands of years and not react in any way.

This chapter looks at the factors controlling the speeds of chemical reactions. It also explores the idea of 'reversibility' in a reaction.



▲ Figure 16.1 Some reactions are very fast.



▲ Figure 16.2 Some reactions happen over several minutes.



▲ Figure 16.3 Rusting takes days or weeks.



▲ Figure 16.4 The weathering of limestone and the formation of stalagmites and stalactites takes a very long time.

LEARNING OBJECTIVES

- Describe experiments to investigate the effects of changes in the surface area of a solid, the concentration of a solution, the temperature and the use of a catalyst on the rate of a reaction
- Describe the effects of changes in the surface area of a solid, the concentration of a solution, the pressure of a gas, the temperature and the use of a catalyst on the rate of a reaction
- Explain the effects of changes in the surface area of a solid, the concentration of a solution, the pressure of a gas and the temperature on the rate of a reaction in terms of particle collision theory
- Know that a catalyst is a substance that increases the rate of a reaction, but is chemically unchanged at the end of the reaction
- Know that a catalyst works by providing an alternative pathway with lower activation energy
- Practical: Investigate the effect of changing the surface area of marble chips and of changing the concentration of hydrochloric acid on the rate of reaction between marble chips and dilute hydrochloric acid
- Practical: Investigate the effect of different solids on the catalytic decomposition of hydrogen peroxide solution
- Know that some reactions are reversible and that this is indicated by the symbol ⇌ in equations
- Describe reversible reactions such as the **dehydration** of hydrated copper(II) sulfate and the effect of heat on ammonium chloride

EXPERIMENTS TO MEASURE THE RATE OF REACTION

The **rate** of a reaction is the speed at which the amount of reactants decreases or the amount of products increases. It is measured as *a change in the concentration (or amount) of reactants or products per unit time* (per second, per minute etc.).

$$\text{rate of reaction} = \frac{\text{change in concentration, volume or mass}}{\text{time}}$$

Safety note: Wear eye protection and avoid skin contact with the acid.

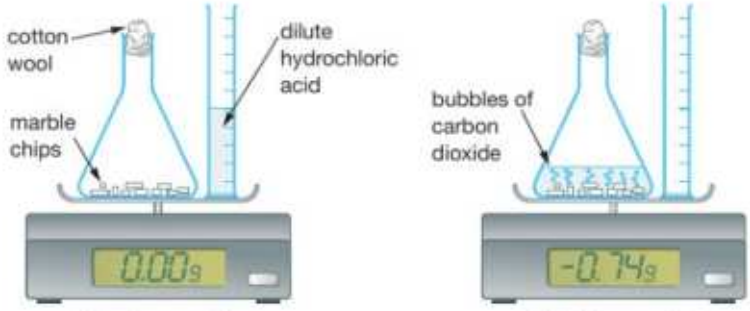
ACTIVITY 5

▼ PRACTICAL: AN INVESTIGATION OF THE RATE OF REACTION BETWEEN MARBLE CHIPS AND DILUTE HYDROCHLORIC ACID

Marble chips are made of calcium carbonate and react with hydrochloric acid to produce carbon dioxide gas. Calcium chloride solution is also formed.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Figure 16.5 shows some apparatus that can be used to measure how the mass of carbon dioxide produced changes with time. Part (a) is drawn as the apparatus would look before the reaction starts.



▲ Figure 16.5 Investigating the reaction between calcium carbonate and hydrochloric acid.

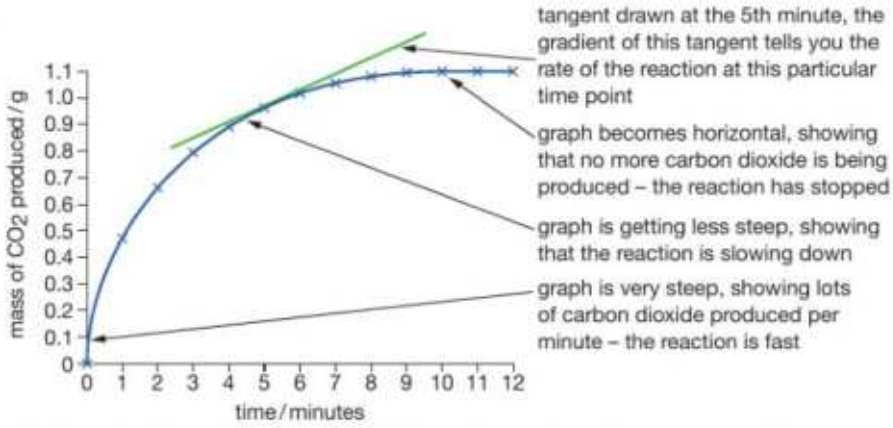
The following procedure could be used:

- Use a measuring cylinder to measure 25 cm^3 of 2.00 mol/dm^3 dilute hydrochloric acid.
- Add 5.00 g of large marble chips to a conical flask and place a piece of cotton wool at the opening of the flask. The cotton wool is there to allow the carbon dioxide to escape during the reaction, but to stop any acid spitting out. The marble is in *excess* – some of it will be left over when the acid is all used up.
- Place everything on a balance and reset it to zero.
- Add the acid to the marble chips and record the reading on the balance every 30 seconds.

Part (b) shows what happens during the reaction. The acid has been poured into the flask and everything has been replaced on the balance. Once the reaction starts, the balance shows a negative mass. The mass goes down because the carbon dioxide escapes through the cotton wool.

When we plot a graph of mass of carbon dioxide lost against time, we obtain something similar to the one in Figure 16.6.

The steeper the slope (gradient) of the line, the faster the reaction. We can see from Figure 16.6 that about 0.47 g of carbon dioxide is produced in the first minute. Only about 0.20 g of extra carbon dioxide is produced in the second minute, the reaction is slowing down.



▲ Figure 16.6 The mass of carbon dioxide lost when calcium carbonate reacts with hydrochloric acid.

HINT

You are unlikely to be asked to draw tangents and find rates like this in an exam.

We can calculate the *average rate* of the reaction during any time interval by using

$$\text{rate} = \frac{\text{mass of } CO_2 \text{ lost}}{\text{time}}$$

For example, the average rate of the reaction in the *first* minute

$$= \frac{0.47}{1} = 0.47\,\text{g/min}$$

The average rate of the reaction in the *second* minute

$$= \frac{0.20}{1} = 0.20\,\text{g/min}$$

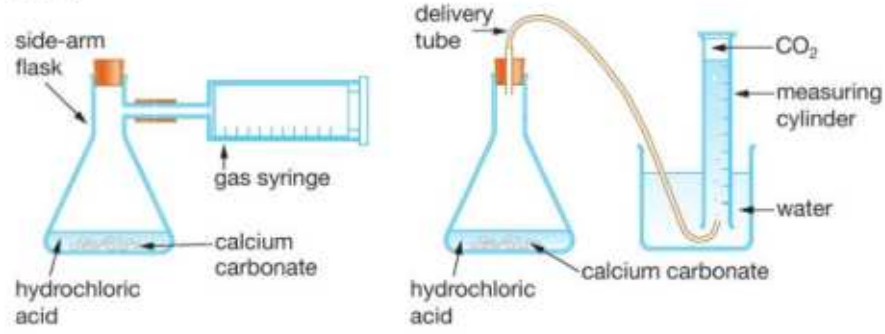
The average rate of the reaction over the *first two* minutes

$$= \frac{0.67}{2} = 0.34\,\text{g/min}$$

We can see the reaction is fastest at the beginning. It then slows down, until it eventually stops because *all the hydrochloric acid has been used up*.

We can measure how fast the reaction is going *at any time point* by finding the slope (gradient) of the line at that point. This is the rate of the reaction *at that point* (rather than the average). This is done by drawing a **tangent** to the line at the time you are interested in and finding its slope (gradient). For example, at 5 minutes the carbon dioxide is being lost at the rate of about 0.05 g per minute (see Figure 16.6).

We can also follow the rate of this reaction by measuring the *volume* of carbon dioxide given off. The apparatus shown in Figure 16.7 can be used.



▲ Figure 16.7 Either method can be used to measure the volume of CO_2 given off.

REMINDER

Remember, the marble chips were in excess (there was more than enough to react with all the hydrochloric acid). There will still be unreacted marble chips in the flask at the end.

EXPLAINING WHAT'S HAPPENING

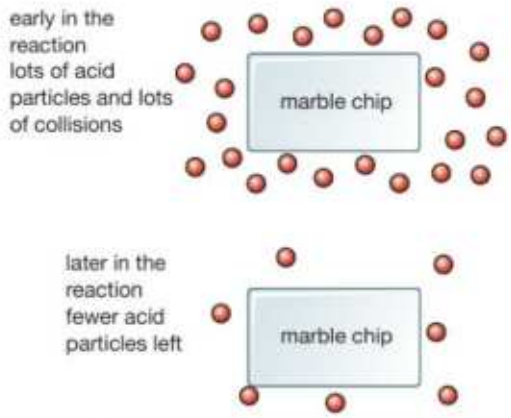
We can explain the shape of the curve by thinking about the particles present and how they interact. This is called the **collision theory**.

Reactions can happen only when particles collide. Not all collisions end up in a reaction. Many particles just bounce off each other. In order for a reaction to actually happen, *the particles have to collide with a minimum amount of energy*, called the **activation energy**. *The collisions with energy greater than or equal to the activation energy* are usually called **successful collisions.**

In the reaction between calcium carbonate and hydrochloric acid, particles in the acid have to collide with the particles at the surface of the marble chips. As the acid particles are getting used up, the collision rate decreases, and so the reaction slows down. The marble is in a large excess so that its shape doesn't change very much during the reaction.

KEY POINT

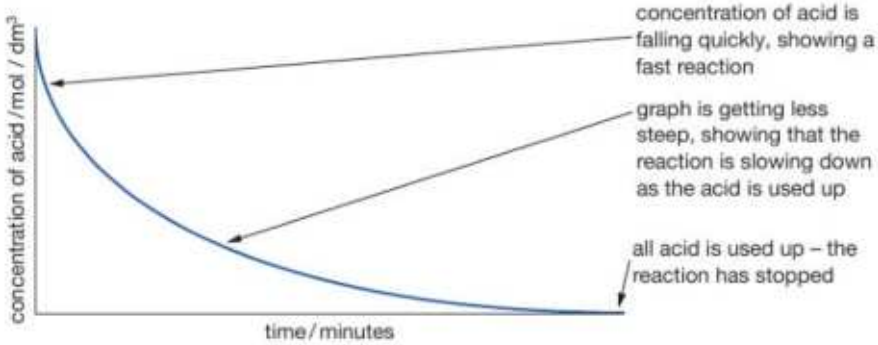
If you have studied Chapter 12, you may realise that the particles we are talking about in the acid are H^+ ions. A reaction occurs when the H^+ ions in the acid collide successfully with the CO_3^{2-} ions in the calcium carbonate. You should not talk about HCl molecules colliding with $CaCO_3$ molecules. If in doubt about what particles are actually colliding, it is probably safer to just use the word *particle*.



▲ Figure 16.8 As the reaction proceeds, the collision rate of acid particles with the marble chips decreases.

A DIFFERENT FORM OF GRAPH

At International GCSE you normally plot graphs showing the mass or volume of product *formed* during a reaction. It is possible, however, that you will see graphs showing the fall in the concentration of one of the *reactants* – in this case, the concentration of the dilute hydrochloric acid.



▲ Figure 16.9 The fall in concentration of hydrochloric acid over time

Where the graph is falling most quickly (is steepest), it shows that the reaction is fastest.

Eventually, the graph becomes horizontal because the reaction has stopped when all the acid has been consumed.

CHANGING THE SURFACE AREA OF THE REACTANTS

ACTIVITY 6

Safety note: Wear eye protection and avoid skin contact with the acid.

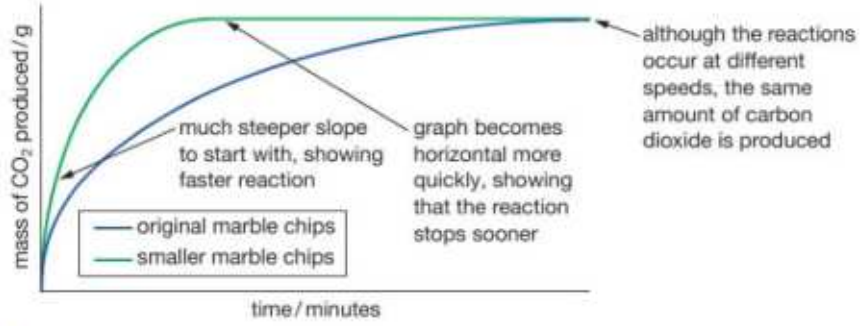
HINT

If we are going to investigate the effect of changing the size of the marble chips, it is important that everything else stays exactly the same to make this a valid (fair) test.

▼ PRACTICAL: INVESTIGATING THE EFFECT OF CHANGING THE SURFACE AREA OF MARBLE CHIPS ON THE RATE OF REACTION BETWEEN MARBLE CHIPS AND DILUTE HYDROCHLORIC ACID

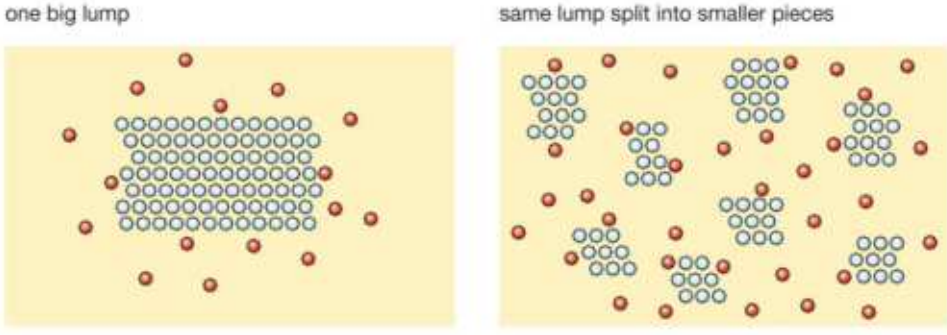
We can repeat the experiment in Activity 5 using exactly the same quantities of everything, but using much smaller marble chips. The reaction with the smaller chips happens faster.

We can plot both sets of results (Activities 5 and 6) on the same graph (Figure 16.10). Notice that the same mass of carbon dioxide is produced because we are using the same quantities of everything in both experiments. However, the reaction with the smaller chips starts off much faster and finishes sooner.



▲ Figure 16.10 The effect of using smaller marble chips

Reactions between solids and liquids (or solids and gases) are faster if the solids are present as a lot of small pieces rather than a few big ones. The more finely divided the solid, the faster the reaction. This is because the *surface area* in contact with the gas or liquid is *much greater* and there are more particles of the solid exposed on the surface. Only the particles on the surface are available for collisions. The *frequency of successful collisions increases* as the surface area of the solid increases.



▲ Figure 16.11 The more divided the solid, the faster the reaction



▲ Figure 16.12 A catalytic converter has a honeycomb structure to give a very large surface area for the exhaust gases to flow through.

Large surface areas are frequently used to speed up reactions outside the lab. For example, a **catalytic converter** for a car uses expensive metals such as platinum, palladium and rhodium coated onto a honeycomb structure in a very thin layer to give the maximum possible surface area.

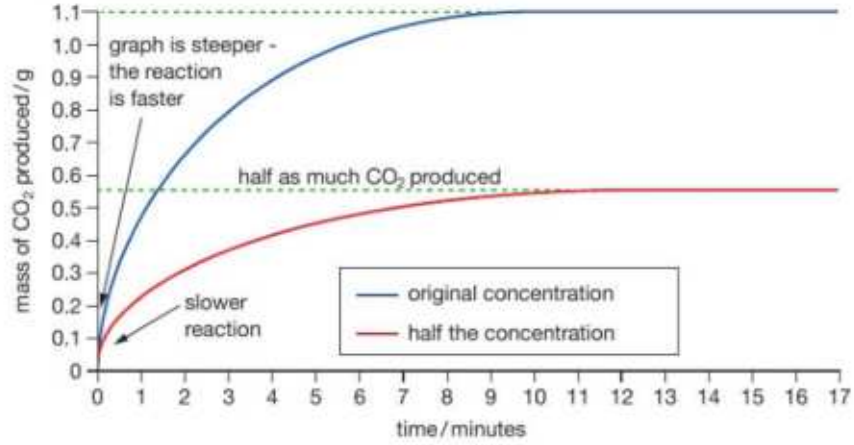
In the presence of these metals, harmful substances such as carbon monoxide and nitrogen oxides are converted into relatively harmless carbon dioxide and nitrogen. The large surface area means the reaction is very rapid. This is important because the gases in the exhaust system are in contact with the catalytic converter for only a very short time.

CHANGING THE CONCENTRATION OF THE REACTANTS

THE EFFECT OF CHANGING THE CONCENTRATION

We can repeat our original experiment with large marble chips and hydrochloric acid. Everything is kept the same except we use hydrochloric acid of half the concentration.

We find that reducing the concentration of the acid makes the reaction slower. We can see this on our graph because the graph (red line) is less steep than for our original experiment (blue line).



▲ Figure 16.13 The effect of changing the concentration of the acid

REMINDER

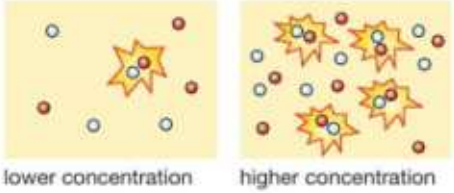
Remember, the marble chips were in excess, so this makes no difference.

In our original experiment we used 25 cm^3 of 2.00 mol/dm^3 hydrochloric acid. In this experiment we used 25 cm^3 of 1.00 mol/dm^3 hydrochloric acid. In the second experiment we have started with half the number of hydrochloric acid particles (half as many moles) and so we will produce half as much carbon dioxide.

KEY POINT

When explaining this, do not only say that there are more collisions. You must always include the idea of time. So, you should say things such as '*the particles collide more frequently or there are more collisions per second*'.

In general, if you increase the concentration of the reactants, the reaction becomes faster. *Increasing the concentration increases the number of acid particles within a fixed volume*, therefore the particles are closer together and collide more frequently. There are *more successful collisions* between the acid particles and the marble chips *every second*.



▲ Figure 16.14 At a higher concentration, more particles collide per second

Safety note: Wear eye protection and avoid skin contact with the acid.

KEY POINT

To calculate the concentration of hydrochloric acid you need to look at the proportions of acid and water. The equation to calculate the concentration of hydrochloric acid is:

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{volume of hydrochloric acid (cm}^3\text{)}}{\text{total volume of solution (25 cm}^3\text{)}} \times \text{original concentration (2.00 mol/dm}^3\text{)}$$

DID YOU KNOW?

The words *proportional* and *directly proportional* mean the same thing. If the graph we plotted was a straight line that did not go through the origin, this is not a proportional relationship. In that case we would describe the relationship as *linear*.

EXTENSION WORK

The relationship between the rate of a reaction and the concentration of the reactants is not always as uncomplicated as it seems. In some reactions, the rate of the reaction is proportional to the concentration of the reactants, as shown by the example in Figure 16.15. We say the reaction is first order with respect to a particular reactant.

If you go on to do chemistry at a higher level, you will come across reactions in which increasing the concentration of one of the reactants has no effect on how fast the reaction happens. These reactions are of zero order with respect to the reactants. In some other cases the rate of a reaction might be proportional to the square of the concentration of a reactant. In this case we say the reaction is of second order with respect to the reactant.

ACTIVITY 7

▼ PRACTICAL: INVESTIGATING THE EFFECT OF CHANGING THE CONCENTRATION OF THE ACID ON THE RATE OF REACTION BETWEEN MARBLE CHIPS AND DILUTE HYDROCHLORIC ACID

We can repeat our previous experiment in Activity 5 using the original large marble chips, but using hydrochloric acid of different concentrations. Everything else would be the same, that is, the mass of the marble chips (5.00 g) and the total volume of the acid (25 cm^3). We can dilute the acid by adding distilled water to the original 2.00 mol/dm^3 solution but making sure the total volume of water and acid remains at 25 cm^3.

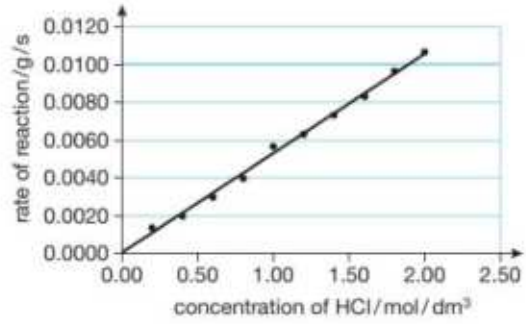
For example, if 12.5 cm^3 of the original HCl is mixed with 12.5 cm^3 of distilled water, we get an acid solution of half of the original concentration (1.00 mol/dm^3). If only 5 cm^3 of the original HCl is mixed with 20 cm^3 of distilled water, the acid solution is now one-fifth (5 out of 25) of the original concentration (0.40 mol/dm^3).

In this experiment we are going to calculate the average rate during the first 30 seconds, so we record the mass of carbon dioxide lost in 30 seconds.

We can calculate the average rate of reaction within the first 30 seconds by dividing the mass loss by 30. For example, if we obtain a loss of 0.32 g:

$$\text{average rate} = \frac{0.32}{30} = 0.011\ \text{g/s}$$

To identify the effect of changing concentration on rate, we can plot the results for the different concentrations on a piece of graph paper with rate on the *y*-axis and concentration of acid on the *x*-axis (Figure 16.15). The line of best fit should go through the origin (0, 0). If there is no acid, there should be no rate. A straight line going through the origin shows that the rate of the reaction is *directly proportional* to the concentration of the hydrochloric acid. If the concentration doubles, the rate should double. If the concentration triples, the rate should triple.

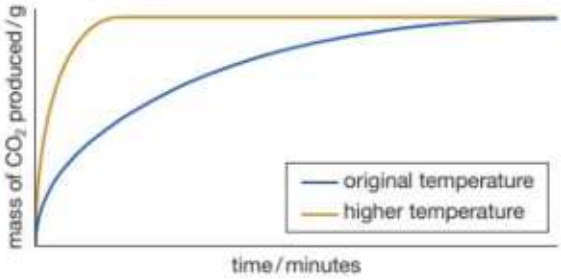


▲ Figure 16.15 The more concentrated the acid, the faster the reaction

CHANGING THE TEMPERATURE OF THE REACTION

We can do the original experiment again, but this time at a higher temperature. We keep everything else exactly the same as before.

Reactions get faster as the temperature is increased; the graph is *steeper* and *finishes sooner*. The same mass of gas is given off because we have used the same quantities of everything in the mixture.



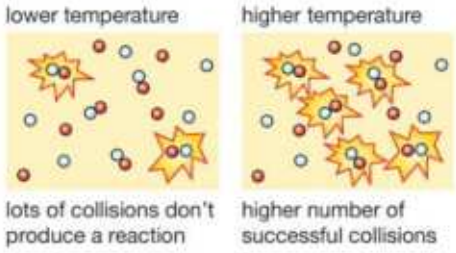
▲ Figure 16.16 The effect of changing the temperature of the reaction

There are two factors that need to be considered when explaining why increasing temperature increases the rate of reaction:

- Increasing the temperature means that the particles are moving faster, and so collide more frequently. That will make the reaction go faster, but it only accounts for a small part of the increase in rate.
- We learned above that in order for a collision to cause a reaction (*a successful collision*), the particles have to collide with a minimum amount of energy, called the *activation energy*. A relatively small increase in temperature produces *a very large increase in the number of particles with energy greater than or equal to the activation energy*. This means that it is going to be much more probable that two particles which have sufficient energy to react collide with each other. So *the frequency of successful collisions increases*.

KEY POINT

As an approximation, a 10 °C increase in temperature approximately doubles the rate of a reaction. This works for quite a lot of reactions that we meet in the lab, as long as the temperature remains within a few tens of degrees of room temperature.



▲ Figure 16.17 A small increase in temperature produces a large increase in the number of collisions with energy greater than the activation energy.

CHANGING THE PRESSURE ON THE REACTION

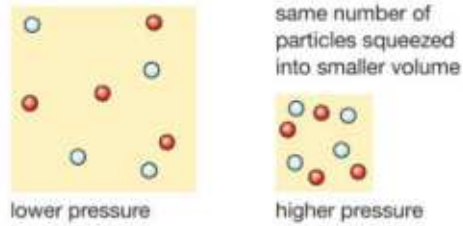
KEY POINT

In solids and liquids, particles are packed closely together and there is hardly any space in between. Increasing the pressure would not change the volumes of the solids or liquids much, therefore there would hardly be any change in the number of particles in a certain volume.

Changing the pressure of a reaction in which the reactants are only solids or liquids makes almost no difference to the rate of reaction. But increasing the pressure of a reaction where the reactants are *gases* does speed up the reaction.

If we have a fixed mass of a gas, we increase the pressure by squeezing it into a smaller volume.

This forces the particles *closer together*, so they *collide more frequently*. This is exactly the same as increasing the concentration of the gas.



▲ Figure 16.18 Increased pressure means gas particles collide more frequently.

CATALYSTS

WHAT ARE CATALYSTS?

Catalysts are *substances that speed up chemical reactions*, but aren't used up in the process. They are still there, *chemically unchanged, at the end of the reaction*. Because they aren't consumed, small amounts of catalyst can be used to process lots and lots of reactant particles. Different reactions need different catalysts.

THE CATALYTIC DECOMPOSITION OF HYDROGEN PEROXIDE



▲ Figure 16.19 Bombardier beetles use hydrogen peroxide as part of their defence mechanism.

Bombardier beetles defend themselves by spraying a hot, unpleasant liquid at their attackers. Part of the reaction involves splitting hydrogen peroxide into water and oxygen, using the enzyme catalase. **Enzymes** are *biological catalysts*. This reaction happens almost explosively, and produces a lot of heat. The same enzyme can be found in potatoes, or even liver tissues.

There are a lot of other things that also catalyse the decomposition of hydrogen peroxide. Some examples are manganese(IV) oxide (also called manganese dioxide), MnO_2, and lead(IV) oxide, PbO_2. Manganese(IV) oxide is what is normally used in the lab to speed up the decomposition of hydrogen peroxide.

The reaction happening with the hydrogen peroxide is:

hydrogen peroxide → water + oxygen

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Notice that we don't write catalysts into the equation because they are chemically unchanged at the end of the reaction. If you like, you can write their name or formula over the top of the arrow.

SHOWING THAT A SUBSTANCE IS A CATALYST



▶ Figure 16.20 The beakers both contain hydrogen peroxide solution, the right-hand one has MnO_2 added to speed up oxygen production.

It isn't difficult to show that manganese(IV) oxide speeds up the decomposition of hydrogen peroxide to produce oxygen. Figure 16.20 shows two beakers, both of which contain hydrogen peroxide solution. Without the catalyst, there is only a trace of bubbles in the solution. With it, oxygen is given off quickly.

How can you show that the manganese(IV) oxide is chemically unchanged by the reaction? It still looks the same, but has any been used up? You can only find out by weighing it before you add it to the hydrogen peroxide solution and then reweighing it at the end.

You can separate the manganese(IV) oxide from the liquid by filtering it through a weighed filter paper, allowing the paper and residue to dry, and then reweighing to calculate the mass of the remaining manganese(IV) oxide. You should find that the mass hasn't changed.

Safety note: Wear eye protection and avoid skin contact with the solution.

HINT

The experiment in Figure 16.21 is very simple and easy to set up. However, using this setup has the disadvantage that some oxygen will escape at the beginning of the reaction when MnO_2 is added to H_2O_2 before the bung can be put back on the conical flask. Using a weighing bottle like the one in Figure 16.22 is a simple way of mixing the chemicals together without losing any oxygen before you can get the bung in. When you are ready to start the reaction, shake the flask so that the weighing bottle falls over and the manganese(IV) oxide comes into contact with the hydrogen peroxide. You need to keep shaking so that an even mixture is formed.

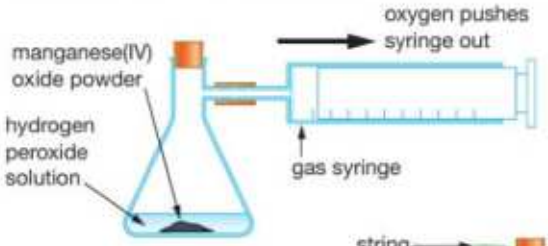
DID YOU KNOW?

'*vol*', meaning volume, is a measurement for concentration for hydrogen peroxide. 1 cm^3 of 2 vol hydrogen peroxide solution decomposes completely to give 2 cm^3 of oxygen.

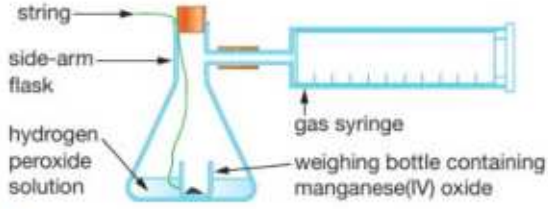
ACTIVITY 8

▼ PRACTICAL: INVESTIGATE THE EFFECT OF DIFFERENT SOLIDS ON THE CATALYTIC DECOMPOSITION OF HYDROGEN PEROXIDE SOLUTION

Figure 16.21 shows apparatus that can be used to measure how the volume of oxygen produced changes with time.



▲ Figure 16.21 Apparatus to measure the volume of oxygen evolved.

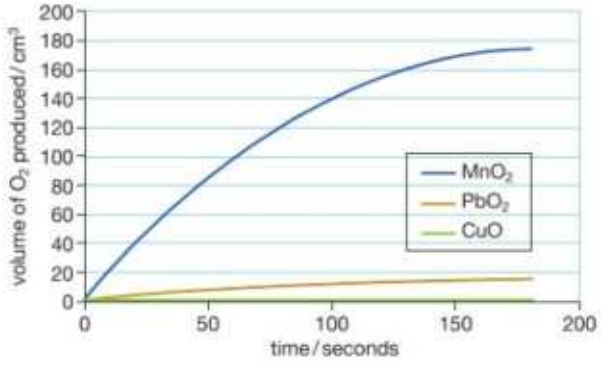


▲ Figure 16.22 Modified apparatus to avoid the loss of oxygen at the beginning of the experiment.

The following procedure could be used:

- Measure 100 cm^3 of 2 *vol* hydrogen peroxide and transfer to a 250 cm^3 conical flask.
- Weigh out 0.20 g of manganese(IV) oxide on a balance.
- Add the manganese(IV) oxide to the hydrogen peroxide and quickly replace the bung with the gas syringe already attached. Swirl the reaction mixture at a constant speed.
- Record the amount of oxygen produced every 20 seconds for 3 minutes and plot a graph of volume of oxygen versus time.
- Repeat the reaction with 0.20 g of lead(IV) oxide and copper(II) oxide but keep everything else the same.

The sample data below show manganese(IV) oxide is a very effective catalyst for the decomposition of hydrogen peroxide. In comparison, lead(IV) oxide is less effective as the rate of the reaction is much slower and copper(II) oxide does not act as a catalyst for this reaction at all.



▲ Figure 16.23 The catalytic effect of different solids on the decomposition of H_2O_2.

HOW DOES A CATALYST WORK?

Not all collisions result in a reaction happening. Collisions have to involve at least a certain minimum amount of energy, called the *activation energy* (page 431).



▲ Figure 16.24 Traffic passes easily through a road tunnel under a mountain.

If a reaction is slow, it means that very few collisions have this amount of energy; when most collisions happen, the particles simply bounce off each other.

Catalysts work by providing an alternative route for the reaction, involving a lower activation energy.

If the activation energy is lower, many more collisions are likely to be successful. The reaction happens faster because many more particles *have energy greater than or equal to the activation energy for the alternative route.* The energy of the particles has not changed but it has been made easier for them to react.

You can illustrate this with a simple everyday example. Imagine you have a mountain between two valleys. Only a few very energetic people will climb over the mountain from one valley to the next. Now imagine building a road tunnel through the mountain. Lots of people will be able to travel easily from one valley to the next.

Be careful how you phrase the statement explaining how a catalyst works. You should say 'Catalysts provide an alternative route with a lower activation energy'.

They *do not* 'lower the activation energy' any more than building a tunnel lowers the mountain. The original route is still there, and if particles collide with enough energy they will still use it, just as very energetic people will still choose to climb over the top of the mountain.

CATALYSTS IN INDUSTRY

Catalysts are especially important in industrial reactions because they help substances to react quickly at lower temperatures and pressures than would otherwise be needed. This saves money.

REVERSIBILITY AND DYNAMIC EQUILIBRIA

TWO REVERSIBLE REACTIONS

DEHYDRATION OF COPPER(II) SULFATE CRYSTALS



▲ Figure 16.25 Copper(II) sulfate crystals are split into anhydrous copper(II) sulfate and water on gentle heating.

If you heat blue copper(II) sulfate crystals gently, the blue crystals turn to a white powder and water is driven off. Heating causes the crystals to lose their *water of crystallisation* and white *anhydrous* copper(II) sulfate is formed. 'Anhydrous' simply means 'without water'.

$$\underset{\text{blue}}{CuSO_4 \cdot 5H_2O(s)} \rightarrow \underset{\text{white}}{CuSO_4(s)} + 5H_2O(l)$$

Heat is needed for this reaction to occur

If you add water to the white solid, it turns blue again; it also becomes very warm. See Figure 14.3 (page 400).

$$\underset{\text{white}}{CuSO_4(s)} + 5H_2O(l) \rightarrow \underset{\text{blue}}{CuSO_4 \cdot 5H_2O(s)}$$

Heat is released from this reaction

The original change has been exactly reversed. Even the heat that you put in originally has been given out again. This is called a **reversible** reaction and is indicated by a special arrow:

$$CuSO_4 \cdot 5H_2O(s) \rightleftharpoons CuSO_4(s) + 5H_2O(l)$$

HEATING AMMONIUM CHLORIDE

If you heat ammonium chloride, the white crystals disappear from the bottom of the tube and reappear further up. Heating ammonium chloride splits it into the colourless gases ammonia and hydrogen chloride.

$$\underset{\text{white solid}}{NH_4Cl(s)} \rightarrow \underset{\text{colourless gases}}{NH_3(g) + HCl(g)}$$ Heat is needed for this reaction to occur

KEY POINT

This reaction is an example of *thermal decomposition*.

These gases recombine further up the tube, where it is cooler, to form a white solid:

$$\underset{\text{colourless gases}}{NH_3(g) + HCl(g)} \rightarrow \underset{\text{white solid}}{NH_4Cl(s)}$$ Heat is released from this reaction

KEY POINT

This is a reaction between an acid (HCl) and a base (NH_3) (see Chapter 13, page 394).

The reaction reverses when the conditions are changed from hot to cool.

HINT

If you add water to the white solid, it turns blue again; it also becomes very warm. See Figure 14.3 (page 400).



◀ Figure 16.26 Heating ammonium chloride

This can, again, be shown with the reversible arrow:

$$NH_3(g) + HCl(g) \rightleftharpoons NH_4Cl(s)$$

CHAPTER QUESTIONS

SKILLS CREATIVITY 

1 A student carried out an experiment to investigate the rate of a reaction between an excess of dolomite (magnesium carbonate) and 50 cm^3 of dilute hydrochloric acid. The dolomite was in small pieces. The reaction is:

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$$

He measured the volume of carbon dioxide given off at regular intervals, with the results shown in the table below.

Time / s	0	30	60	90	120	150	180	210	240	270	300	330	360
Volume / cm^3	0	27	45	59	70	78	85	90	94	97	99	100	100

a Draw a diagram of the apparatus you would use for this experiment and label it.

SKILLS INTERPRETATION

b Plot these results on a piece of graph paper, with time on the *x*-axis and volume of gas on the *y*-axis.

SKILLS ANALYSIS, REASONING 

c At what time is the gas being given off most quickly? Explain why the reaction is fastest at that time.

SKILLS PROBLEM SOLVING 

d Use your graph to find out how long it took to produce 50 cm^3 of gas.



e Use your graph to calculate the average rate of this reaction in the first 80 seconds.

SKILLS REASONING

f In each of the following questions, state and explain what would happen to the initial rate of the reaction and to the total volume of gas given off if various changes were made to the experiment.

i The mass of dolomite and the volume and concentration of acid were kept constant, but the dolomite was in one big lump instead of small pieces.

ii The mass of dolomite was unchanged and it was still in small pieces. 50 cm^3 of hydrochloric acid was used, which had half the original concentration.

iii The dolomite was unchanged again. This time 25 cm^3 of the original acid was used instead of 50 cm^3.

iv The acid was heated to 40 °C before the dolomite was added to it.

2 The effect of concentration and temperature on the rate of a reaction can be explored using the reaction between magnesium ribbon and dilute sulfuric acid:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

A student dropped a 2 cm length of magnesium ribbon into 25 cm^3 of dilute sulfuric acid (a large excess of acid) in a boiling tube. She stirred the contents of the tube continuously and timed how long it took for the magnesium to disappear.

a What would you expect to happen to the time taken for the reaction if the student repeated the experiment using the same length of magnesium with a mixture of 20 cm^3 of acid and 5 cm^3 of water? Explain your answer in relation to the collision theory.

b What would you expect to happen to the time taken for the reaction if she repeated the experiment using the original quantities of magnesium and acid, but first heated the acid to 50 °C? Explain your answer in relation to the collision theory.

c Give a reason why is it important to keep the reaction mixture stirred continuously.

3 Catalysts speed up reactions, but can be recovered chemically unchanged at the end of the reaction.

a Explain how a catalyst works to increase the rate of reactions.

SKILLS DECISION MAKING

b Describe how you would find out whether iron(III) oxide was a catalyst for the decomposition of hydrogen peroxide solution. Note: you need to show not only that it speeds the reaction up, but that it is chemically unchanged at the end.

SKILLS REASONING

4 The thermal decomposition of ammonium chloride is a reversible reaction.

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$$

a Explain how the equation shows that the reaction is reversible.

SKILLS CRITICAL THINKING

b Give one observation associated with the **forward reaction**.

UNIT QUESTIONS

SKILLS ANALYSIS, PROBLEM SOLVING

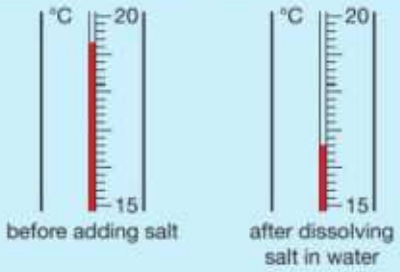
1

A group of students wanted to investigate the energy changes when salts dissolve in water. The teacher suggested that they should measure the temperature changes that occur when the salts were dissolved.

This is the method they followed:

- Add 100 cm^3 of water to a beaker.
- Record the temperature of the water.
- Weigh 5.00 g of salt and add it to the water in the beaker.
- Stir the mixture with a glass rod vigorously until all the solid has dissolved.
- Record the maximum (or minimum) temperature of the solution.

a The diagram below shows the readings on the thermometer before and after the student dissolved a salt, potassium chloride, in water.



before adding salt — after dissolving salt in water

i Write down the thermometer readings and calculate the temperature change. **(3)**

Temperature before ..... °C

Temperature after ..... °C

Temperature change ..... °C

SKILLS CRITICAL THINKING

ii Which of the following statements is true about the dissolving of potassium chloride in water (choose one answer)? **(1)**

A The process is endothermic and ΔH is positive.

B The process is exothermic and ΔH is positive.

C The process is endothermic and ΔH is negative.

D The process is exothermic and ΔH is negative.

SKILLS PROBLEM SOLVING

b Another student repeated the experiment with a different salt, calcium chloride, using the same method and recorded these results.

Volume of water = 100 cm^3

Starting temperature of water = 15.9 °C

Maximum temperature of solution = 23.2 °C

Mass of salt = 5.00 g

i Calculate the heat energy released in this experiment. The specific heat capacity of the solution c = 4.2 J/g/°C and the mass of 1 cm^3 of mixture = 1 g. **(3)**

ii How many moles of calcium chloride dissolved in the solution? **(2)**

iii Work out the molar enthalpy change, in kJ/mol, for dissolving calcium chloride in water. **(2)**

SKILLS REASONING

c Another student dissolved magnesium chloride in water. She compared her result with a data book value.

Student's value = −105 kJ/mol

Data book value = −141 kJ/mol

There are no errors in the calculation of her result.

Suggest two reasons why the student's value differs from the data book value. **(2)**

(Total 13 marks)

SKILLS PROBLEM SOLVING

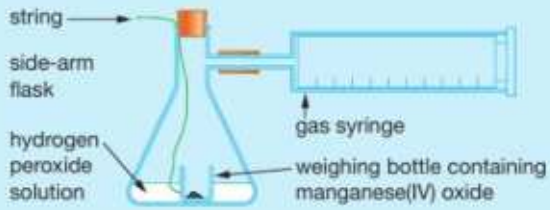
2 In an experiment to investigate the rate of decomposition of hydrogen peroxide solution in the presence of manganese(IV) oxide, a student mixed 10 cm^3 of hydrogen peroxide solution with 30 cm^3 of water and added 0.20 g of manganese(IV) oxide. She measured the volume of oxygen evolved at 60 s intervals. The results of her experiment are recorded in the table below.

Time / s	0	60	120	180	240	300
Volume / cm^3	0	30	48	57	60	60

a Write a balanced equation for the decomposition of hydrogen peroxide. **(2)**

SKILLS REASONING

b Explain why the manganese(IV) oxide was added in a weighing bottle rather than directly into the hydrogen peroxide solution. **(1)**



SKILLS INTERPRETATION

c Plot a graph of her results and draw a line of best fit. Make sure that you label the axes. **(4)**

SKILLS ANALYSIS, PROBLEM SOLVING

d Use your graph to find out the following:

i How long it took to produce 50 cm^3 of oxygen. **(1)**

ii The volume of gas produced after 100 seconds. **(1)**

iii The average rate (with unit) in the first 150 seconds. **(2)**

SKILLS ANALYSIS, PROBLEM SOLVING

e Explain why the graph becomes horizontal after 240 seconds. **(2)**

SKILLS CRITICAL THINKING

f Manganese(IV) oxide acts as a catalyst for this reaction.

i A catalyst speeds up a chemical reaction by (choose one answer): **(1)**

A increasing the number of collisions between the reactant particles.

B providing an alternative reaction pathway with lower activation energy.

C increasing the energy of the reactant particles.

D changing the enthalpy of the reaction.

SKILLS DECISION MAKING

ii Describe a method you could use to show that the manganese(IV) oxide is acting as a catalyst in this reaction. **(4)**

SKILLS INTERPRETATION

g Suppose the experiment had been repeated using the same quantities of everything, but with the reaction flask immersed in ice.
Sketch the graph you would expect to get. Use the same grid as in c.
Label the new graph **G**. **(2)**

h On the same grid as in c and g sketch the graph you would expect to get if you repeated the experiment at the original temperature using 5 cm^3 of hydrogen peroxide solution, 35 cm^3 of water and 0.20 g of manganese(IV) oxide. Label this graph **H**. **(2)**

(Total 22 marks)

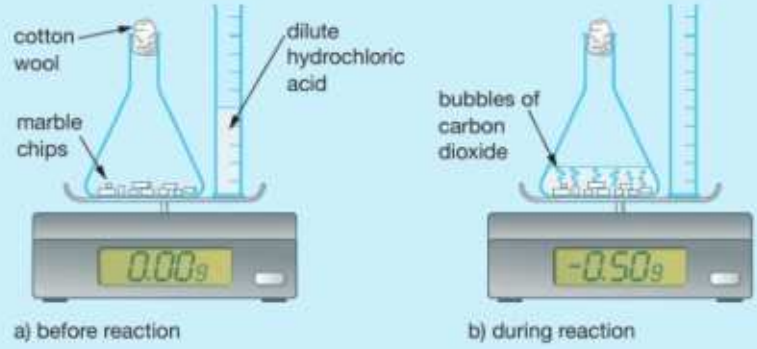
SKILLS EXECUTIVE FUNCTION

3 A group of students investigated the effect of changing the concentration of dilute hydrochloric acid on the rate of its reaction with marble chips (calcium carbonate).

The equation for this reaction is

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

They used the following method:



a) before reaction b) during reaction

The students recorded the time taken for the mass of the flask and contents to decrease by 0.50 g.

The experiment was then repeated using different concentrations of hydrochloric acid.

a To ensure it was a valid (fair) test, the students kept the number of marble chips constant in each experiment. Suggest two other properties of the marble chips that should be kept the same in each experiment. **(2)**

SKILLS CRITICAL THINKING 5th

b What is the purpose of the cotton wool? **(1)**

c The teacher gave the students some hydrochloric acid that was labelled 100%. The table below shows the results.

Students	Mass of $CaCO_3$ / g	Volume of 2.00 mol / dm^3 HCl / cm^3	Volume of water / cm^3	Concentration of HCl / %	Time to lose 0.50 g / s
1	5.00	25	0	100	105
2	5.00	20	5	80	150
3	5.00	15		60	175
4	5.00	10	15	40	272
5	5.00	5	20	20	520

SKILLS PROBLEM SOLVING 6th

i The results of Student 3 are incomplete.
Calculate the volume of water the student should have used for the result to be comparable with the other four (choose one answer). **(1)**

A 5

B 10

C 15

D 20

SKILLS INTERPRETATION 7th

ii Plot a graph of the results on a separate piece of graph paper, with concentration of acid on the *x*-axis and time on the *y*-axis.
Draw a line of best fit. **(4)**

SKILLS ANALYSIS, PROBLEM SOLVING 5th

iii Use your graph in ii to find the time taken for the loss of 0.50 g of mass from the flask when the concentration of acid is 70%. **(1)**

SKILLS REASONING

iv One of the points on the graph is anomalous. Identify a reason for this (choose one answer). **(1)**

A The student started the stopwatch too late.

B The student stopped the stopwatch before mass loss reached 0.50 g.

C The student added too much water at the beginning of the experiment.

D The student spilt some water before adding it into the reaction mixture.

d Another group of students repeated the experiment, but this time they measured the mass loss after 1 minute.

The table below shows the results obtained by the students.

Mass of carbon dioxide given off / g	0.36	0.72	0.88	1.28	1.44	1.65
Concentration of acid / mol/dm^3	0.20	0.40	0.50	0.70	0.80	0.90

i Describe the relationship between the mass of carbon dioxide given off in 1 minute and the concentration of the acid. **(2)**

7th

ii Explain this relationship in terms of particles. **(3)**

(Total 15 marks)

SKILLS REASONING

4 During the manufacture of nitric acid from ammonia, the ammonia is oxidised to nitrogen monoxide, NO, by oxygen in the air.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

The ammonia is mixed with air and passed through a stack of large circular gauzes made of platinum–rhodium alloy at red heat (about 900 °C). The platinum–rhodium gauzes act as a catalyst for the reaction.

a Gas particles have to collide before they can react. Use the collision theory to help you to answer the following questions.

i Because the gases are in contact with the catalyst for only a very short time, it is important that the reaction happens as quickly as possible. Explain why increasing the temperature to 900 °C makes the reaction very fast. **(3)**

ii Explain what will happen to the reaction rate if the pressure is increased. **(2)**

iii Explain why the platinum–rhodium alloy is used as gauzes rather than as pellets. **(2)**

b Platinum and rhodium are extremely expensive metals. Explain why the manufacturer can justify their initial cost. **(2)**

(Total 9 marks)

5 At temperatures above 150 °C, brown nitrogen dioxide gas dissociates (splits up reversibly) into colourless nitrogen monoxide and oxygen:

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g) \qquad \Delta H = +114 \text{ kJ/mol}$$

a Write down the meaning of the symbols $\rightleftharpoons$ and ΔH. **(2)**

b What does the positive sign of ΔH indicate about the reaction? **(1)**

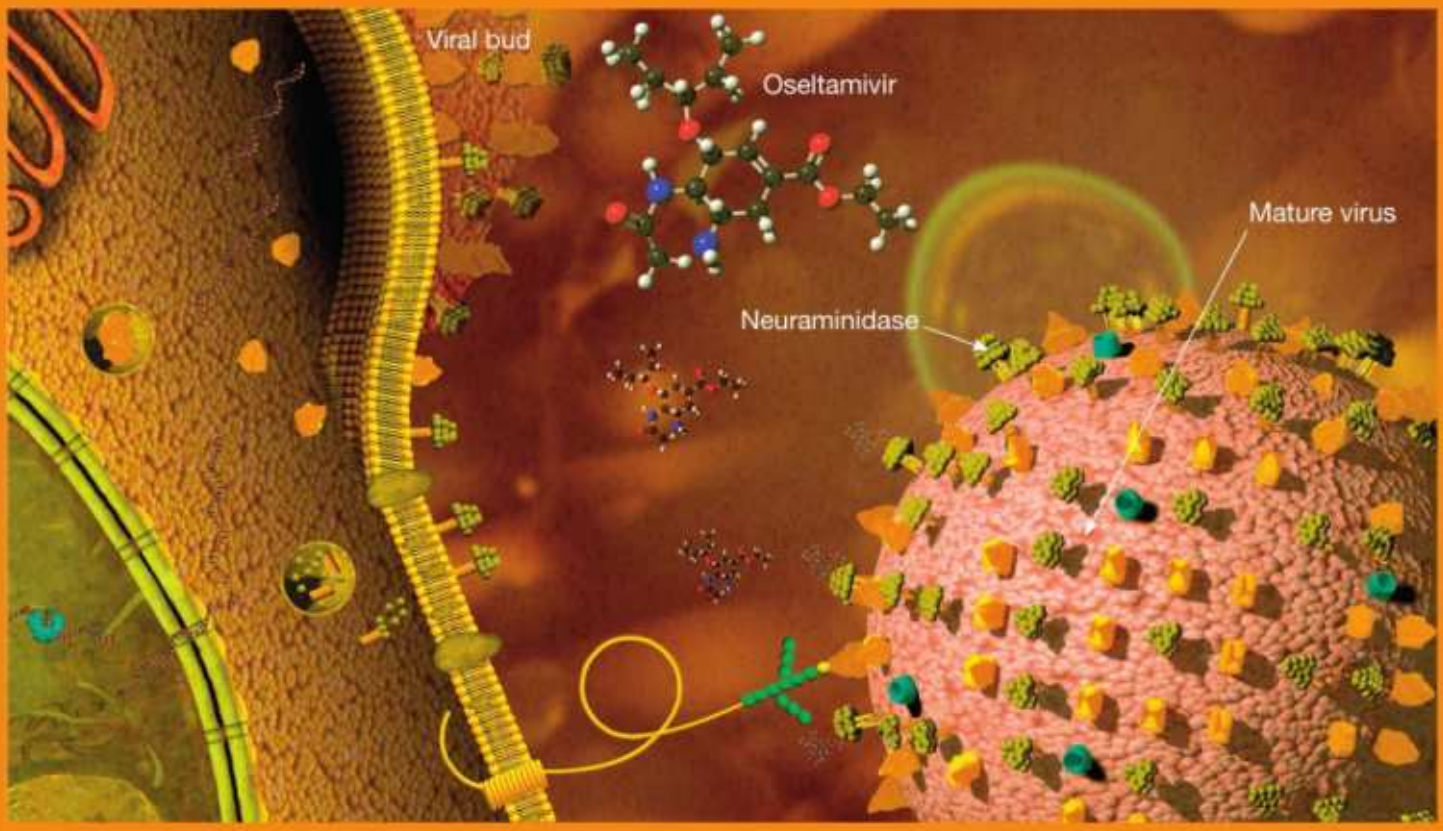
c Give one observation associated with the backward reaction. **(1)**

(Total 4 marks)

INTRODUCTION TO ORGANIC CHEMISTRY 447 | CRUDE OIL 459 | ALKANES 468 | ALKENES 473
SYNTHETIC POLYMERS 478

CHEMISTRY UNIT 4 ORGANIC CHEMISTRY

Organic chemistry is the study of the compounds of carbon (there are some inorganic carbon compounds as well). There are more organic compounds than all the other compounds put together. These compounds include naturally occurring ones that are found in our bodies, for example proteins, DNA and fats. There are also artificially made compounds such as plastics, dyes and drugs. The artificial compounds are derived from chemicals obtained from crude oil. When all the crude oil has been used we will have to find new sources for more than just fuel for cars and making electricity. Organic chemists are involved in the synthesis of a huge variety of new compounds, including drugs and medicines used to treat diseases such as cancer, AIDS, influenza and asthma. The synthesis of these drugs can involve a large number of steps and requires the knowledge and understanding of a great number of organic chemistry reactions. It can take many years and millions of dollars to develop a new drug.



17 INTRODUCTION TO ORGANIC CHEMISTRY

There are millions of different organic compounds. They all contain carbon and hydrogen, and often other elements such as oxygen, nitrogen and chlorine. Carbon atoms can join together to form chains and rings, which is why there are so many carbon compounds. This chapter introduces you to some of the important ideas that you need to know before you can start to understand organic chemistry.





▲ Figure 17.1 What do caffeine, aspirin and dyes have in common? They are all organic compounds.

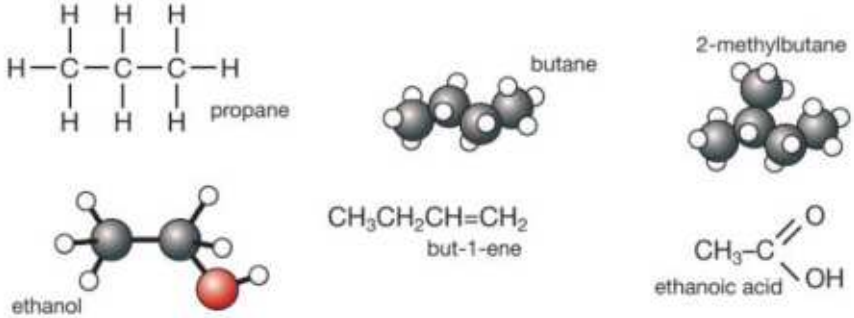
LEARNING OBJECTIVES

- Know that a hydrocarbon is a compound made up of hydrogen and carbon only
- Understand how to represent organic molecules using empirical formulae, molecular formulae, general formulae, structural formulae and displayed formulae
- Know what is meant by the terms homologous series, functional group and isomerism
- Understand how to name compounds (containing up to six carbon atoms) using the rules of International Union of Pure and Applied Chemistry (IUPAC) nomenclature
- Understand how to write the possible structural and displayed formulae of an organic molecule given its molecular formula
- Understand how to classify reactions of organic compounds as substitution, addition and combustion

In the next few chapters we will be looking at organic compounds. The term 'organic' was originally used because it was believed that organic compounds could only come from living things. Now it is used for any carbon compound except for the very simplest (carbon dioxide, carbon monoxide, the carbonates and the hydrogencarbonates).

Organic compounds can exist as chains, branched chains or rings of carbon atoms with hydrogens attached.

When you start doing organic chemistry, you are suddenly faced with a whole lot of new compounds with strange names and unfamiliar ways of drawing them. It can be quite scary!



▲ Figure 17.2 Organic chemistry involves a lot of new compounds.

HINT

Your school may have models you can use. Otherwise, you can make your own out of modelling clay and matchsticks or small nails to use as bonds.

The secret at the beginning is to spend a lot of time exploring the subject – understanding names, drawing structures and making models.

HYDROCARBONS

The simplest organic compounds are **hydrocarbons**. *These are molecules that contain carbon and hydrogen only.*

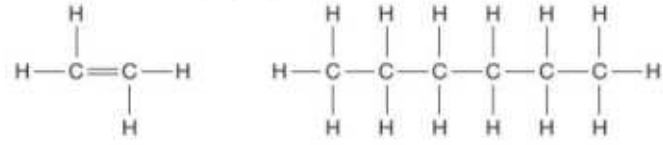
HINT

The word *only* is important here. Virtually all organic compounds contain carbon and hydrogen but hydrocarbons contain *only* carbon and hydrogen.

The carbon atoms are joined together with single, double or triple bonds. Carbon atoms are joined to hydrogen atoms by single bonds.

KEY POINT

Organic compounds can be described as **saturated** (containing only single C–C bonds) or **unsaturated** (containing double or triple C–C bonds). This is discussed in Chapters 19 and 20.



ethene hexane

▲ Figure 17.3 Examples of hydrocarbons

TYPES OF FORMULA FOR ORGANIC MOLECULES

EMPIRICAL FORMULAE

REMINDER

Empirical and molecular formula are introduced in Chapter 5.

An **empirical formula** tells you *the simplest whole number ratio of the atoms in a compound*. It can be calculated from experimental data. Without more information, it is not possible to identify the 'true' or 'molecular' formula. Sometimes the empirical formula is the same as the molecular formula. For example, the empirical formula of methane is CH_4, which is the same as its molecular formula. However, the empirical formula of ethane is CH_3 whereas its molecular formula is C_2H_6.

MOLECULAR FORMULAE

A **molecular formula** *counts the actual number of each type of atom present in a molecule*. For example, the molecular formula of butane is C_4H_{10} and the molecular formula of ethene is C_2H_4.

The molecular formula is a multiple of the empirical formula. For example, if a compound has empirical formula CH_2, the molecular formula could be C_2H_4, C_3H_6, C_4H_8, etc. The ratio of C:H must always be the same as in the empirical formula.

The molecular formula tells you nothing about the way the atoms are joined together. Both the compounds in Figure 17.4 have the same molecular formula.



▲ Figure 17.4 These two compounds have the same molecular formula but different structures.

Molecular formulae are used very rarely in organic chemistry because they don't give any useful information about the bonding in the molecule. You might use them in equations for the combustion of simple hydrocarbons, where the structure of the molecule doesn't matter. For example:

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$$

In almost all other cases, you use a structural or a displayed formula.

GENERAL FORMULAE

There are many different families of organic compounds, known as **homologous series**. Examples of homologous series are alkanes and alkenes. These homologous series will be discussed in more detail in later chapters.

A homologous series is a *series of compounds with similar chemical properties because they have the same functional group. Each member differs from the next by one –CH_2–.*

Members of a homologous series can be represented using a **general formula**. The first few members of the alkane series are shown in Table 17.1.

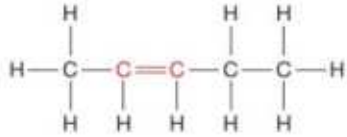
Table 17.1 The first few members of the alkane and alkene homologous series

Alkanes	Alkenes
CH_4	
C_2H_6	C_2H_4
C_3H_8	C_3H_6
C_4H_{10}	C_4H_8

In the case of alkanes, if there are n carbons in a molecule, there are always $2n + 2$ hydrogens. The general formula of alkanes is C_nH_{2n+2}. For methane, CH_4, there is 1 carbon atom in the molecule and $2 \times 1 + 2 = 4$ hydrogen atoms. For propane C_3H_8, there are 3 carbon atoms in the molecule and $2 \times 3 + 2 = 8$ hydrogen atoms. We can therefore work out that dodecane, which has 12 carbon atoms, will have 26 hydrogen atoms and the molecular formula $C_{12}H_{26}$.

Different homologous series usually have different general formulae. For example, the general formula for alkenes is C_nH_{2n}.

A **functional group** is *an atom or a group of atoms that determine the chemical properties of a compound*. All compounds in the same homologous series have the same functional group. For example, the functional group for alkenes is C=C.



▲ Figure 17.5 Alkenes contain the C=C functional group.

HINT

More features of a homologous series are discussed on page 469.

HINT

A way of thinking about this is: the functional group is what makes the behaviour of a particular compound different from that of an alkane.

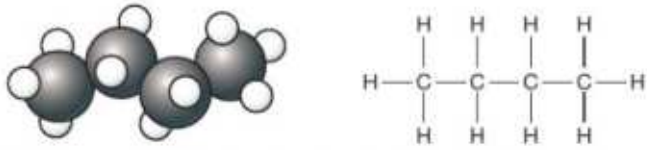
STRUCTURAL FORMULAE

A **structural formula** shows *how the atoms in a molecule are joined together*. There are two ways of representing structural formulae: they can be drawn as a **displayed formula** (full structural formula), or they can be written out in condensed form (*condensed structural formula*) by omitting all the carbon–carbon single bonds and carbon–hydrogen single bonds, for example $CH_3CH_2CH_3$. You need to be confident about using either way.

DISPLAYED FORMULAE

A displayed formula (sometimes called a full structural formula) shows *all* the bonds in the molecule as individual lines. You need to remember that each line represents *a pair of shared electrons in a covalent bond*.

Figure 17.6 shows a model of butane, together with its displayed formula. Notice that the way the displayed formula is drawn is different from the shape of the actual molecule. Displayed formulae are always drawn with the molecule straightened out and flattened. They do, however, show exactly how all the atoms are joined together.



▲ Figure 17.6 Butane. The angles between neighbouring C–H bonds in butane are shown as 90° in the two-dimensional displayed formula. In reality they are about 109.5° in a tetrahedral arrangement in three dimensions, similar to the arrangement of C–C bonds in a diamond structure (see Chapter 7, page 334).

REMINDER

It is important to remember when you draw structures that C always forms four bonds and H always forms one bond. Oxygen will form two bonds and a halogen (chlorine, bromine, etc.) atom one. If you are not sure about why these atoms form this number of bonds, you need to look back at Chapter 7.

KEY POINT

If you are asked to draw the structure for a molecule in an International GCSE exam, always draw it as a displayed formula. You can't lose any marks by doing this, whereas you might if you use the simplified form. If, on the other hand, you are simply writing a structure in an equation, for example, you can use whichever version you prefer.

HOW TO DRAW A STRUCTURAL FORMULA

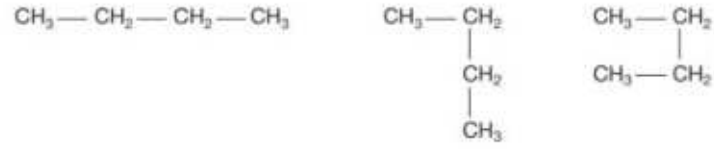
For anything other than the smallest molecules, drawing a fully displayed formula is very time-consuming. You can simplify the formula by writing, for example, CH_3 or CH_2 instead of showing all the carbon–hydrogen bonds.

The structural formula for butane can be shown as

$CH_3CH_2CH_2CH_3$ or $CH_3{-}CH_2{-}CH_2{-}CH_3$

These both show exactly how the atoms in the molecule are joined together. The corresponding molecular formula, C_4H_{10}, doesn't give you the same sort of useful information about the molecule.

All the structures in Figure 17.7 represent butane: even though they look different they are exactly the same molecule.



▲ Figure 17.7 All three structures represent butane. The convention is to write the structure with all the carbon atoms in a straight line.

HINT

The best way to understand that these are all the same is to make some models. If you don't have access to molecular models, use blobs of modelling clay joined together with pieces of matchstick or small nails to represent the bonds. You will find that you can change the shape of the model by rotating around the bonds. That's what happens in real molecules.

Each structure shows four carbon atoms joined together in a chain, but the chain has simply twisted. This happens in real molecules as well: the atoms can rotate around single carbon–carbon bonds, as shown in Figure 17.8.

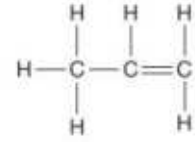


▲ Figure 17.8 These diagrams show the shape of a butane molecule better, but you would not draw these in an exam.

KEY POINT

Structural formulae may be drawn in various ways. Sometimes no bonds are shown and other times some bonds are shown. The easiest way to think about it is like this: if all the bonds are shown, then it is a displayed formula but if not all of them are shown (but you can still see what the structure is), then it is a structural formula.

A molecule like propene, C_3H_6, has a carbon–carbon double bond. This is shown by drawing two lines between the carbon atoms to show *the two pairs of shared electrons*. You would normally write this in a simplified structural formula as $CH_3CH{=}CH_2$.



▲ Figure 17.9 The displayed formula for propene

KEY POINT

In more advanced work the structural formula of propene would just be written as CH_3CHCH_2 but at International GCSE the C=C will normally be shown.

NAMING ORGANIC COMPOUNDS

Names for organic compounds can appear quite complicated, but they are simply a code that describes the molecule. Each part of a name tells you something specific about the molecule. One part of a name tells you how many carbon atoms there are in the longest chain, another part tells you whether there are any carbon–carbon double bonds, and so on.

CODING THE CHAIN LENGTH

Look for the code letters in the name – these are given in Table 17.2.

Table 17.2 Coding the chain length

Code letters	Number of carbons in chain
meth	1
eth	2
prop	3
but	4
pent	5
hex	6

HINT

You have to learn these! The first four are the difficult ones because there isn't any pattern. However, a mnemonic can help, something like **M**onkeys **E**at **P**ink **B**ananas. Or you could think of one of your own that you can remember!
'**Pent**' means five (as in **pent**agon) and '**hex**' means six (as in **hex**agon).

For example, **but**ane has a chain of four carbon atoms. **Prop**ane has a chain of three carbon atoms.

CODING FOR THE TYPE OF COMPOUND

ALKANES

Alkanes are *a homologous series of similar hydrocarbons (compounds of carbon and hydrogen only) in which all the carbons are joined to each other with single covalent bonds*. Compounds like this are coded with the ending '**ane**'. For example, eth*ane* is a two-carbon chain (because of 'eth') with a carbon–carbon single bond, $CH_3—CH_3$.

HINT

In more complicated molecules, the presence of the code 'an' in the name again shows that the carbons are joined by single bonds. For example, you can tell that propan-1-ol contains three carbon atoms ('prop') joined together by carbon–carbon single bonds ('an'). The coding on the end gives you more information about the molecule. You will meet this later in the chapter.

ALKENES

Alkenes are *a homologous series of hydrocarbons which contain a carbon–carbon double bond*. This is shown in their name by the ending '**ene**'. For example, eth*ene* is a two-carbon chain containing a carbon–carbon double bond, $CH_2=CH_2$. With longer chains, the position of the double bond could vary in the chain. This is shown by numbering the chain and noting which carbon atom the double bond *starts* from.

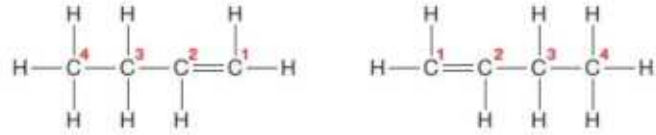
Table 17.3 Indicating the position of the double bond in the name of alkenes

Formula	Name	Description
$CH_2=CHCH_2CH_3$	but-1-ene	a four-carbon chain with a double bond starting on the first carbon
$CH_3CH=CHCH_3$	but-2-ene	a four-carbon chain with a double bond starting on the second carbon

HINT

Both parts of Figure 17.10 show the same molecule, but in one case it has been turned over so that what was originally on the left is now on the right, and vice versa. It would be silly to change the name every time the molecule moved! Both of the forms in Figure 17.10 are called but-1-ene.

How do you know which end of the chain to number from? The rule is that *you number from the end which produces the smaller numbers in the name*.



▲ Figure 17.10 Both structures represent but-1-ene.

CODING FOR BRANCHED CHAINS

Hydrocarbon chains can have side branches on them. You are only likely to come across two small side chains, shown in Table 17.4.

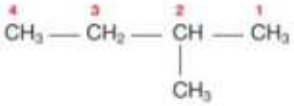
Table 17.4 Coding for branched chains

Side chain	Coded
CH_3–	methyl
CH_3CH_2–	ethyl

KEY POINT

Notice that the count of the number of carbons in the side chain is coded exactly as before: '**meth**' shows a *one*-carbon side chain, '**eth**' shows *two* carbons. The 'yl' shows that the group is attached to something else.

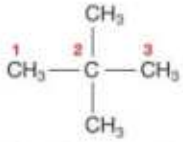
The name of a molecule is always based on the longest chain you can find in it. *The position of the side chain is shown by numbering the carbon atoms from the end of the longest chain which produces the smaller numbers in the name*, exactly as before with the carbon–carbon double bonds in alkenes.



▲ Figure 17.11 Number from the end that produces the smaller number for the side chain branch.

The longest chain in the molecule in Figure 17.11 has four carbon atoms ('but') with no double bonds ('ane'). The name is based on butane. There is a methyl group branching from the number 2 carbon. (Remember to number from the end that produces the smaller number.) The compound is called 2-methylbutane.

Where there is more than one side chain, you describe the position of each of them.



▲ Figure 17.12 Describe the position of each side chain.

The longest chain in the molecule in Figure 17.12 has three carbon atoms and no double bonds. Therefore the name is based on propane.

There are two methyl groups attached to the second carbon. The compound is 2,2-dimethylpropane. The '*di*' in the name shows the presence of the two methyl groups. '2,2' shows that they are both on the second carbon atom.

You can reverse this process and draw a structural formula from a name. All you have to do is decode the name.

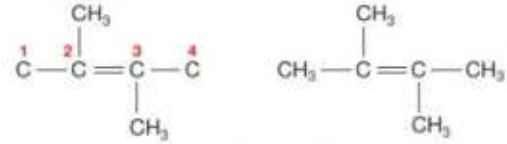
For example, what is the structural formula for 2,3-dimethylbut-2-ene?

Start by looking for the code for the longest chain length. 'but' shows a four-carbon chain. 'ene' shows that it contains a carbon–carbon double bond starting on the second carbon atom ('-2-ene'). There are two methyl groups ('dimethyl') attached to the second and third carbon atoms in the chain ('2,3-'). All you have to do now is to fit all this together into a structure.

HINT

It is much more important to be able to decode names to give structures than the other way around. If you don't know what a teacher or an examiner is talking about, you are completely lost!

Start by drawing the structure without any hydrogen atoms on the main chain. It doesn't matter whether you draw the CH_3 groups pointing up or down. Then add enough hydrogens so that each carbon atom forms four bonds. Figure 17.13 shows how your thinking would work.



▲ Figure 17.13 First draw the carbon structure, then add hydrogens.

KEY POINT

Warning! Don't confuse the word isomer with isotope. *Isotopes* are different atoms of the same element with the same atomic number but different mass numbers.

STRUCTURAL ISOMERISM

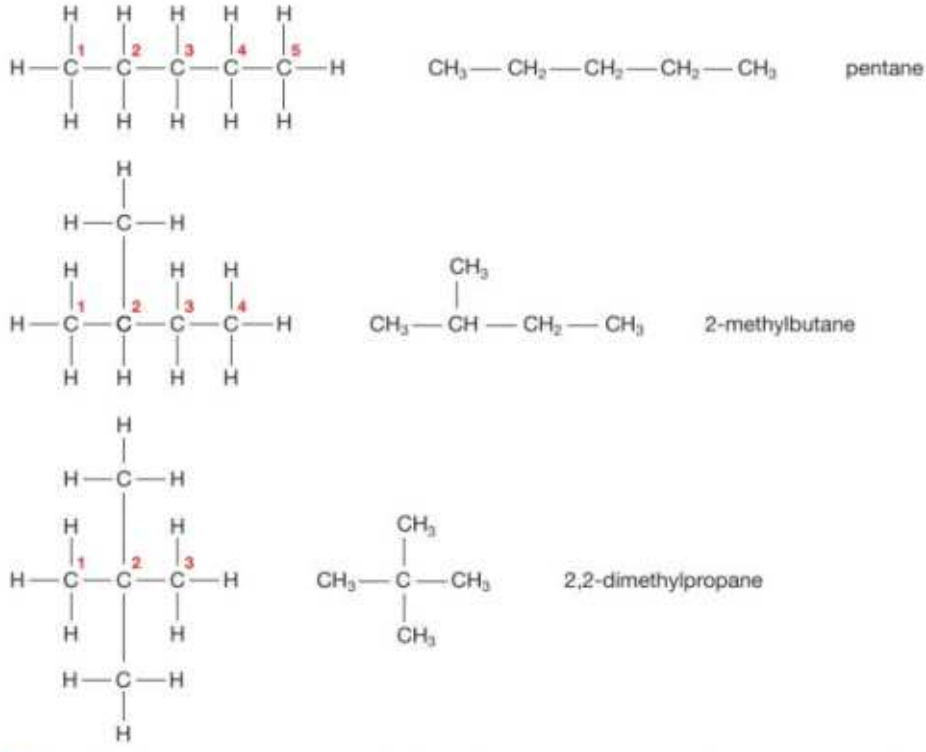
Structural isomers *are molecules with the same molecular formula, but different structural formulae.*

Examples will make this clear.

STRUCTURAL ISOMERISM IN THE ALKANES

ISOMERS OF C_5H_{12}

If you had some molecular models and picked out five carbon atoms and 12 hydrogen atoms, you would find it was possible to join them together in more than one way. The different molecules formed are known as isomers. All have the molecular formula C_5H_{12}, but different structures.



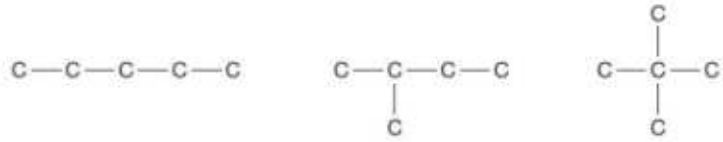
▲ Figure 17.14 There are three isomers for C_5H_{12}. These can be shown as either displayed formulae or structural formulae.

If you look carefully at the structures in Figure 17.14 you can see that you couldn't change one into the other simply by bending or twisting the molecule. You would have to break some bonds and reconnect the atoms. That's a simple way of telling that you have isomers.

HINT

It is sometimes easier to see that the molecules are different by drawing only the C atoms joined together, without the hydrogens.

But you must show the hydrogen atoms in the exam!



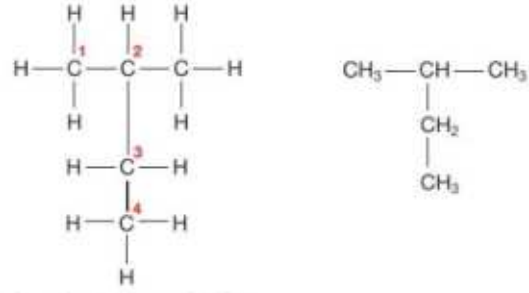
REMINDER

A straight chain is an unbranched chain.

The **straight chain** isomer is called pentane. The *branched chain* isomer in the middle, which has a four-carbon chain ('butane') and a methyl group on the second carbon, is called 2-methylbutane. The final *branched chain* isomer, which has a three-carbon chain ('propane') and two methyl groups on the second carbon, is called 2,2-dimethylpropane. The prefix '*di*' indicates the presence of two identical branches in the molecule.

Students frequently think they can find another isomer as well. If you look closely at this 'fourth' isomer (Figure 17.15) you will see that it is just 2-methylbutane rotated in space.

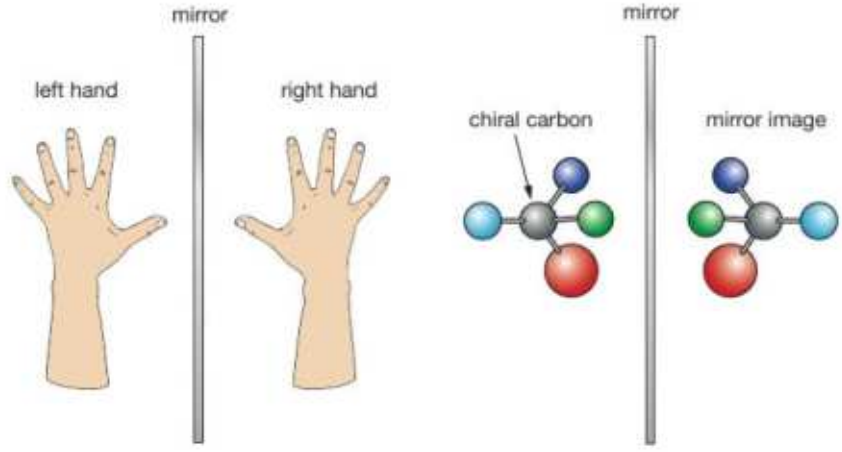
To avoid this sort of problem, always draw your isomers so that *the longest carbon chain is drawn horizontally* (or draw them out again without the H atoms).



▲ Figure 17.15 There is no fourth isomer for C_5H_{12}.

LOOKING AHEAD

To be precise, the type of isomerism discussed here should be called **structural isomerism**: molecules have the same molecular formula but different structural formulae. The atoms in the different isomers are joined in a different order. There are also other forms of isomerism and one important type is called optical isomerism. Optical isomers have atoms joined in the same order (i.e. they have the same structural formula), but are arranged differently in three-dimensional space. These isomers are mirror images of each other but cannot be superimposed. A good analogy is to look at your left and right hands. They are exactly the opposite of each other but cannot lie on top of another and align perfectly (Figure 17.16).



▲ Figure 17.16 Optical isomers are mirror images of each other and cannot be superimposed.

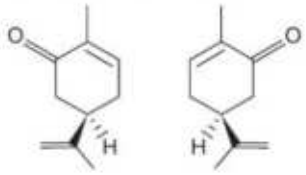
Optical isomerism occurs when a molecule has a *chiral centre*, that is to say it has a carbon atom that is connected to four different atoms or groups of atoms. These molecules have a tetrahedral shape around the chiral centre (molecular shape was mentioned in Chapter 7, pages 329–330). Figure 17.16 shows two molecules that are mirror images of each other. However, if you rotate one of the molecules 180° in space, it cannot be put on top of the other.

Optical isomers have identical chemical properties, except when they interact with something that is also chiral. For example, apart from glycine, all naturally occurring amino acids have optical isomers, which means that all the proteins in our body are chiral. This is why we can distinguish the two optical isomers in

EXTENSION WORK

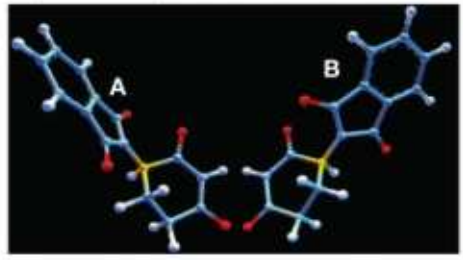
The optical isomers are assigned a prefix (*R* or *S*) to show the configuration of atoms around the chiral centre.

Figure 17.17. One smells of spearmint and the other of caraway seed because the two molecules interact differently with the protein receptors in our noses.



(R) (S)

▲ Figure 17.17 Two optical isomers of carvone



▲ Figure 17.18 Optical isomerism in drug molecules

An important application of optical isomerism is in the synthesis of pharmaceutical drugs. You might have heard of the thalidomide tragedy. Back in the 1960s in Germany, the molecule B shown in Figure 17.18 was found to have anti-nausea effects and was therefore used to treat morning sickness in pregnant woman. Unfortunately, molecule B was being manufactured together with its optical isomer A and little was known about the molecule A until many children born in that era were found to have deformed limbs. These days, many drug companies devote a great deal of money to separating optical isomers of new drugs just in case they have side effects.

STRUCTURAL ISOMERISM IN THE ALKENES

ETHENE AND PROPENE

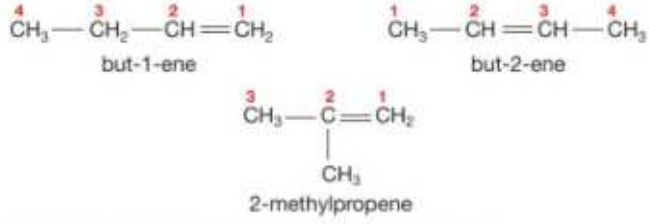
Ethene, $CH_2{=}CH_2$, doesn't have any isomers. Propene, $CH_3CH{=}CH_2$, doesn't have a structural isomer that is still an alkene.

EXTENSION WORK

There is a structural isomer of C_3H_6 that doesn't have a carbon–carbon double bond. It has three carbon atoms joined in a ring. It is called cyclopropane, which indicates 'a ring of three carbons with only single bonds between them'.

ISOMERS OF C_4H_8

There are three structural isomers with the molecular formula C_4H_8 and containing a carbon–carbon double bond.



▲ Figure 17.19 Structural isomers with the molecular formula of C_4H_8.

HINT

If you aren't comfortable with the names, see pages 450–452 on organic names.

Notice the way that you can vary the position of the double bond as well as branching the chain.

SOME CHEMICAL REACTIONS OF ORGANIC COMPOUNDS

In this section we will look at how to classify the reactions of organic compounds. These reactions will be explained much more in the next few chapters.

COMBUSTION

All organic compounds that you will meet at International GCSE undergo combustion reactions. Combustion is just another way of saying *burning* and involves a reaction with oxygen.



▲ Figure 17.20 The burning of a camping stove

Combustion of hydrocarbons in *excess oxygen* gives rise to *carbon dioxide* and *water*, together with the release of a large amount of heat energy. For example:

propane burning $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

butene burning $C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(l)$

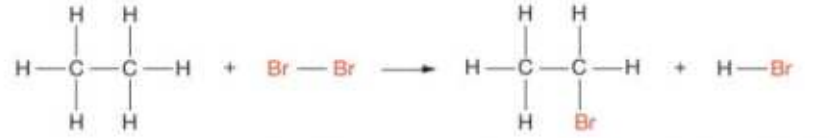
Propane is frequently used in camping stoves outdoors.

SUBSTITUTION

A **substitution** reaction occurs when an atom or group of atoms is *replaced* by a different atom or group of atoms. For example, the hydrogen atoms in an alkane can be replaced by halogen atoms. We will go into more detail on this reaction in Chapter 19.

ethane with bromine gas

$$CH_3CH_3(g) + Br_2(g) \rightarrow CH_3CH_2Br(g) + HBr(g)$$



▲ Figure 17.21 A substitution reaction between an alkane and a halogen

ADDITION

In an **addition** reaction something is added to a molecule without taking anything away. Alkenes undergo addition reactions. For example, ethene reacts with bromine:

ethene with Br_2

$$CH_2CH_2(g) + Br_2(l) \rightarrow CH_2BrCH_2Br(l)$$



▲ Figure 17.22 An addition reaction between an alkene and a halogen.

CHAPTER QUESTIONS

Note: the questions below deliberately include some examples which are slightly beyond the level which you would expect to meet in an International GCSE exam.

SKILLS CRITICAL THINKING

6th 7th

1 a Write down the names of the following hydrocarbons:

i CH_4

ii $CH_3CH_2CH_3$

iii $CH_3CH_2CH_2CH_2CH_2CH_3$

iv $CH_3CH{=}CH_2$

v $CH_2{=}CH_2$

vi $CH_2{=}CHCH_2CH_3$

SKILLS INTERPRETATION

b Draw structural and displayed formulae for:

i ethane
ii but-2-ene
iii hexane
iv 2-methylpropane
v methylpropene
vi pent-1-ene

SKILLS CRITICAL THINKING

2 a Explain the term *structural isomerism*.

SKILLS INTERPRETATION

b There are two structural isomers of C_4H_{10}. Draw their structures and name them.

c There are five structural isomers of C_6H_{14}. Draw their structures and name them.

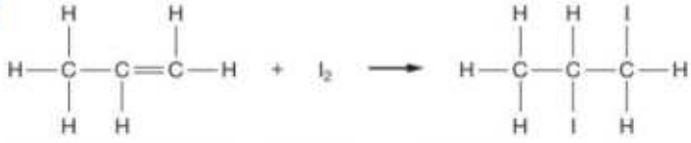
SKILLS CRITICAL THINKING

d How many structural isomers containing a carbon–carbon double bond can you find with a molecular formula C_4H_8? Name the straight chain isomers.

SKILLS INTERPRETATION

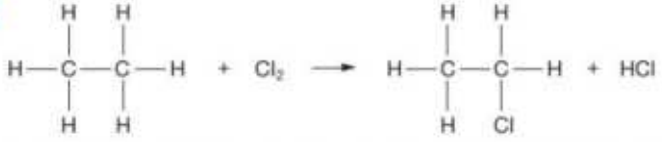
e Draw two isomers of C_4H_8 that do not contain carbon–carbon double bonds.

3 Classify the following reactions as substitution, addition or combustion.

a 

b $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$

c $C_4H_8(g) + H_2(g) \rightarrow C_4H_{10}(g)$

d 

e $CH_3CH_2CH_2CH_3(g) + Br_2(g) \rightarrow CH_3CH_2CHBrCH_3(g) + HBr(g)$

SKILLS CRITICAL THINKING

4 The table below shows the formulae of some organic compounds.

Compound	Formula
A	C_2H_6
B	$CH_3CH{=}CH_2$
C	$CH_3CH_2CH_2OH$
D	$CH_3CH_2CH_2CH_2CH_3$

a Select one compound from the table which is not a hydrocarbon. Explain your choice.

SKILLS INTERPRETATION

b Draw a dot-and-cross diagram to show the bonding in compound **A**.

c Draw the full displayed formula of compound **B**. Include all bonds in your drawing.

SKILLS CRITICAL THINKING

d Compounds **A** and **D** are from the same homologous series. State the general formula for this homologous series.

e Other than having the same general formula, state *one* other characteristic of members of the same homologous series.

SKILLS PROBLEM SOLVING

f Write a balanced chemical equation for the complete combustion of compound **D**.

18 CRUDE OIL

The oil industry is at the very heart of modern life. It provides fuels, plastics and the organic chemicals which go to make things as different as solvents, drugs, dyes and explosives. This chapter explores how an unappealing, sticky, black liquid is converted into useful things.



▲ Figure 18.1 The oil industry is BIG business!

LEARNING OBJECTIVES

- Know that crude oil is a mixture of hydrocarbons
- Describe how the industrial process of fractional distillation separates crude oil into fractions
- Know the names and uses of the main fractions obtained from crude oil: refinery gases, gasoline, kerosene, diesel, fuel oil and bitumen
- Know the trend in colour, boiling point and viscosity of the main fractions
- Know that a fuel is a substance that, when burned, releases heat energy
- Know the possible products of complete and incomplete combustion of hydrocarbons with oxygen in the air
- Know that in car engines the temperature reached is high enough to allow nitrogen and oxygen from air to react, forming oxides of nitrogen
- Explain how the combustion of some impurities in hydrocarbon fuels results in the formation of sulfur dioxide
- Understand how sulfur dioxide and oxides of nitrogen contribute to acid rain
- Describe how long-chain alkanes are converted to alkenes and shorter-chain alkanes by catalytic cracking (using silica or alumina as the catalyst and a temperature in the range of 600–700 °C)
- Explain why cracking is necessary in terms of the balance between supply and demand for different fractions
- Understand why carbon monoxide is poisonous, in terms of its effect on the capacity of blood to transport oxygen

WHAT IS CRUDE OIL?

THE ORIGIN OF CRUDE OIL

Millions of years ago, plants and animals living in the sea died and fell to the bottom. Layers of sediment formed on top of them. Their shells and skeletons formed limestone. The soft tissue was gradually changed by heat and high pressure into **crude oil**. Crude oil is a *finite*, ***non-renewable resource***. Once all the existing supplies have been used, they won't be replaced, or at least not for many millions of years.



▲ Figure 18.2 This sticky black liquid is essential to modern life.

CRUDE OIL CONTAINS HYDROCARBONS

Crude oil is a mixture of hydrocarbons, *compounds containing carbon and hydrogen only*. There are lots of different hydrocarbons of various sizes in crude oil, ranging from molecules with just a few carbon and hydrogen atoms to molecules containing over 100 atoms.

HOW THE PHYSICAL PROPERTIES OF HYDROCARBONS CHANGE WITH MOLECULE SIZE

As the number of carbon atoms in hydrocarbon molecules increases, the physical properties of the compounds change. Most of these changes are the result of increasing attractions between neighbouring molecules. *As the molecules become bigger, the intermolecular forces of attraction become stronger* and it becomes more difficult to pull one molecule away from its neighbours.

REMINDER

Intermolecular forces are explained in Chapter 7 (page 333).

As the molecules become bigger, the following changes occur.

- *Boiling point increases*: the larger the molecule, the higher the boiling point. This is because large molecules are attracted to each other more strongly than smaller ones. More energy is needed to break these stronger intermolecular forces of attraction to produce the widely separated molecules in the gas.
- *The liquids become less* **volatile**: the bigger the hydrocarbon, the more slowly it evaporates at room temperature. This is again because the bigger molecules are more strongly attracted to their neighbours and so don't turn into a gas so easily.
- *The liquids become more* **viscous** *and flow less easily*: liquids containing small hydrocarbon molecules are runny. Those containing large molecules flow less easily because of the stronger forces of attraction between their molecules.
- The liquids become darker in colour.
- Bigger hydrocarbons do not burn as easily as smaller ones. This limits the use of the bigger ones as fuels.

HINT

We usually count a substance as being volatile if it turns to a vapour easily at room temperature. That means it will evaporate quickly at that temperature.

SEPARATING CRUDE OIL

Crude oil itself has no uses and it has to be separated into *fractions* before it can be used. These fractions are all mixtures, but each one contains a narrow range of sizes of hydrocarbons with similar boiling points. We use **fractional distillation** to separate crude oil into fractions. This is carried out in an oil refinery.

FRACTIONAL DISTILLATION

Crude oil is heated until it boils and the vapours pass into a **fractionating column**, which is cooler at the top and hotter at the bottom. The vapours rise up the column. How far up the column a particular hydrocarbon moves depends on its boiling point.

KEY POINT

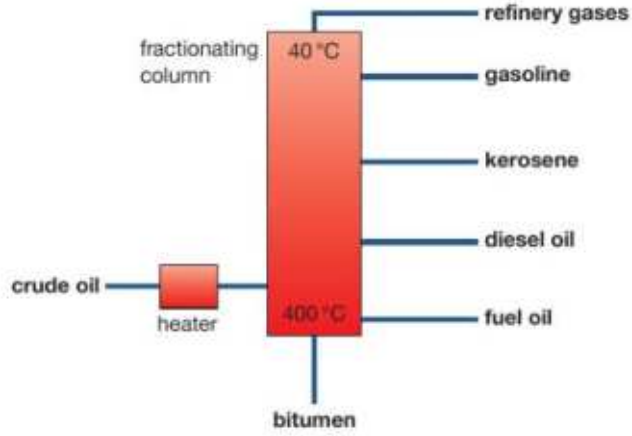
The boiling point is the same as the temperature at which a gas condenses to form a liquid; it could also be called the *condensation point*.

Suppose a hydrocarbon boils at 120 °C. At the bottom of the column, the temperature is much higher than 120 °C and so the hydrocarbon remains as a gas. As it travels up the column, the temperature of the column becomes lower. When the temperature falls to 120 °C, that hydrocarbon will turn into a liquid, it *condenses* and can be removed.

Smaller molecules have lower boiling points and get further up the column before they condense. Longer chain hydrocarbons have higher boiling points and condense lower down in the column. This way, the crude oil is split into various *fractions*.

HINT

You will find a lot of disagreement, from various sources, about exactly what fractions are produced in fractional distillation. Figure 18.3 matches the requirements of the Edexcel International GCSE specification, but this is a major simplification of what really goes on.



▲ Figure 18.3 Fractional distillation of crude oil

The hydrocarbons in the refinery gas fraction (see Figure 18.3) have very small masses and their boiling points are so low that the temperature of the column never falls low enough for them to condense to liquids. The temperature of the column isn't hot enough to boil some of the very large hydrocarbons found in the crude oil, and so they remain as a liquid. These are removed as a residue from the bottom of the column. Bitumen (see below), which is used in road making, is made from this.

USES OF THE FRACTIONS

AS FUELS

All hydrocarbons burn in air (oxygen) to form *carbon dioxide and water*, and release a lot of heat in the process. The various fractions can therefore be used as **fuels**.

A fuel is a substance which, when burned, releases heat energy.

HINT

Don't try to learn these equations as there are too many possible hydrocarbons you could be asked about. Provided you know (or are told) the formula of the fuel and remember the products of the combustion reaction, you can balance the equation yourself.

For example, burning methane (the major constituent of natural gas):

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

or burning octane (one of the hydrocarbons present in gasoline, petrol):

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

If there isn't enough air (or oxygen), you get **incomplete combustion**. This leads to the formation of *carbon (soot)* or *carbon monoxide* instead of carbon dioxide.

For example, if methane burns in a badly maintained gas appliance, there may not be enough oxygen available to produce carbon dioxide, and so you get toxic carbon monoxide instead:

$$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l)$$

The formation of carbon monoxide from the incomplete combustion of hydrocarbons is very dangerous. Carbon monoxide is colourless and odourless, and is very poisonous. *Carbon monoxide is poisonous because it reduces the ability of the blood to carry oxygen around the body*. This will make you ill, or you may even die, because not enough oxygen gets to the cells in your body for respiration to provide energy.



▲ Figure 18.4 As well as all the other poisonous or cancer-causing compounds, cigarette smoke contains carbon monoxide due to incomplete combustion.

DID YOU KNOW?

Carbon monoxide combines with *haemoglobin* (the molecule that carries oxygen in the red blood cells), preventing it from carrying the oxygen. It binds more strongly to the haemoglobin than oxygen does.

EXTENSION WORK

If you try to draw a dot-and-cross diagram for carbon monoxide, you will see that it is a very strange molecule because carbon does not form four bonds.

REFINERY GASES

Refinery gases are *a mixture of methane, ethane, propane and butane*, which can be separated into individual gases if required. These gases are commonly used as liquefied petroleum gas (LPG) for domestic heating and cooking.

GASOLINE (PETROL)

As with all the other fractions, petrol is a mixture of hydrocarbons with similar boiling points. It is used as a fuel in cars.

KEROSENE

Kerosene is used as a fuel for jet aircraft, as domestic heating oil and as 'paraffin' for small heaters and lamps.



▲ Figure 18.5 Kerosene is used as aviation fuel.

DIESEL

This is used as a fuel for buses, lorries, some cars, and some railway engines. Some is also converted to other more useful organic chemicals, including petrol, in a process called *cracking* (see page 464–466 for more details on cracking).



▲ Figure 18.6 A train powered by diesel

FUEL OIL

This is used as a fuel for ships and for industrial heating.



▲ Figure 18.7 Ships' boilers burn fuel oil.

BITUMEN

Bitumen is a thick, black material, which is melted and mixed with small pieces of rock to make the top surface of roads.



▲ Figure 18.8 Bitumen is used in road construction.

ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE BURNING OF FOSSIL FUELS FROM CRUDE OIL

KEY POINT

Fossil fuels include coal, gas and fuels derived from crude oil. These all come from things that were once alive.

There are major environmental problems associated with the burning of fossil fuels derived from crude oil. First of all, the carbon dioxide produced when hydrocarbons are burned is a greenhouse gas. Greenhouse gases *trap the heat radiated from the Earth's surface (originally from the Sun)* and many people believe that this could lead to climate change. For more discussion on the greenhouse effect, see Chapter 10.

ACID RAIN: SULFUR DIOXIDE AND OXIDES OF NITROGEN

KEY POINT

Several oxides of nitrogen are involved, including NO and NO_2. They are often given the general formula NO_x.

Rain is naturally slightly acidic (pH = ~5.6) because of dissolved carbon dioxide. Acid rain is rain with a pH lower than this (pH < 5.6) because of the presence of various pollutants. The pH of acid rain is often about 4.

Acid rain *is formed when water and oxygen in the atmosphere react with sulfur dioxide to produce sulfuric acid (H_2SO_4), or with various oxides of nitrogen, NO_x, to give nitric acid (HNO_3).* SO_2 and NO_x come mainly from power stations and factories burning fossil fuels, or from motor vehicles.

Fossil fuels contain a small amount of sulfur. When the fuel is burned, the sulfur reacts with oxygen, producing sulfur dioxide:

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

Reactions in the atmosphere with oxygen and water can convert this to *sulfuric acid (H_2SO_4)*, a strong acid and an important component of acid rain:

$$2SO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 2H_2SO_4(aq)$$

Note: when sulfur dioxide reacts with water, a weaker acid called *sulfurous acid (H_2SO_3)* is formed:

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$



▲ Figure 18.9 Use of very low-sulfur fuels limits the production of sulfur dioxide, but the spark in a petrol engine causes oxygen and nitrogen from the air to combine to make oxides of nitrogen, NO_x.

In petrol engines, **sparks** are used to ignite the petrol–air mixture to power the car. The temperature reached in the engine is high enough to allow nitrogen and oxygen in the air to combine to produce oxides of nitrogen. For example:

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

These nitrogen oxides can be converted to *nitric acid (HNO_3)* in the atmosphere and therefore contribute to acid rain.



▲ Figure 18.10 Trees dying from the effects of acid rain.

Acid rain is a major problem, mainly because of its devastating effect on trees and on life in lakes. Acid rain kills trees and fish in lakes. In some lakes the water is so acidic that it won't support life at all. Limestone buildings and marble statues (both made of *calcium carbonate*) and some metals such as iron are also attacked by acid rain.

Reaction between limestone and sulfuric acid:

$$CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$$

The solution to acid rain involves removing sulfur from fuels (this is usually done for petrol used in cars), '**scrubbing**' the gases from power stations and factories to remove SO_2 and NO_x, and using catalytic converters in cars.

CRACKING

Although most of the fractions from the fractional distillation of crude oil are useful as fuels, some fractions are more useful and more profitable to sell than others.

The amounts of each fraction obtained will depend on the proportions of the various hydrocarbons in the original crude oil, not the amounts in which they are needed. The problem is:

- there are far too many long-chain hydrocarbons, which are not in such high demand and are not as profitable to sell
- there are not enough shorter-chain hydrocarbons that can be used as fuel for cars.

Far more petrol is needed than can be supplied by just separating crude oil into its fractions.

Cracking is a process in which *long-chain alkanes are converted to alkenes and shorter-chain alkanes*. The big hydrocarbon molecules in fuel oil, for example, can be broken down into the smaller ones needed for petrol. A very simple equation could be:

$$\underset{\text{alkane}}{C_{14}H_{30}} \rightarrow \underset{\text{alkane}}{C_{10}H_{22}} + \underset{\text{alkene}}{C_4H_8}$$

HOW CATALYTIC CRACKING WORKS

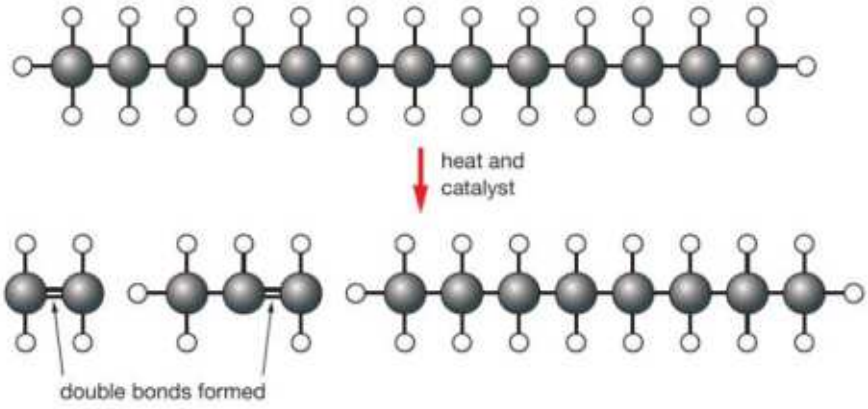
The fuel oil fraction is heated to give a gas and then passed over a catalyst of *silicon dioxide* (also called silica) and *aluminium oxide* (also called alumina) at about *600–700 °C*. Cracking can also be carried out at higher temperatures without a catalyst (*thermal cracking*).

Cracking is just an example of *thermal decomposition*: a big molecule splitting into smaller ones on heating. The majority of the hydrocarbons found in crude oil have single bonds between the carbon atoms. During the cracking process, C–C single bonds are broken and new C=C double bonds are formed.

The molecules are broken up in a fairly random way. One possibility is shown in Figure 18.11.

REMINDER

In Figure 18.11, the molecules have been drawn to show the various covalent bonds. They have also been 'straightened out' with bond angles of 90°.



▲ Figure 18.11 How cracking works.

As an equation, this would read:

$$C_{13}H_{28}(l) \rightarrow C_2H_4(g) + C_3H_6(g) + C_8H_{18}(l)$$

HINT

Don't worry too much if you can't remember which are gases and which are liquids. State symbols are very commonly missed out in organic chemistry.

Cracking produces a mixture of alkanes and alkenes. In this case, two different alkenes are produced: ethene and propene. Octane, an alkane, is also formed. This particular cracking reaction has therefore produced two types of useful molecules for the chemical industry. Ethene and propene are both used to make important polymers. Both are also used in making other organic chemicals. The reaction also produces octane, which is a component of petrol (gasoline).

There are therefore two important reasons why oil companies carry out cracking:

- to produce more petrol
- to produce more alkenes that can be used for making polymers (plastics) (alkenes are more reactive than alkanes and also have other uses).

HINT

It is essential that you don't try to learn these equations. In an exam, you could be given one of a wide range of possible hydrocarbons to start with. You need to understand what is happening, so that you can be adaptable.

The molecule might have split quite differently. All sorts of reactions are happening in a catalytic cracker. Two other possibilities might be:

$$C_{13}H_{28}(l) \rightarrow 2C_2H_4(g) + C_9H_{20}(l)$$

$$C_{13}H_{28}(l) \rightarrow 2C_2H_4(g) + C_3H_6(g) + C_6H_{14}(l)$$

Some reactions might even produce a small percentage of free hydrogen. For example:

$$C_{13}H_{28}(l) \rightarrow 2C_2H_4(g) + C_3H_6(g) + C_6H_{12}(l) + H_2(g)$$

In this case, all the hydrocarbons formed will have double bonds. They are all alkenes.

There will also be very many other ways in which this particular molecule might have split up. Also, remember that the fraction being cracked contains a complex mixture of hydrocarbons, not just one. At the end of the cracking process you will have an equally complex mixture of smaller hydrocarbons, both alkanes and alkenes. This mixture will have to go through a lot of further processing (including further fractional distillation) to separate everything out into pure compounds.

EXTENSION WORK

In industry, catalytic cracking is done by passing hydrocarbons through a bed of zeolite (aluminosilicate) catalyst at about 500 °C and moderate pressures. Apart from breaking down large straight-chain molecules into smaller ones, isomerisation can occur during the process to produce branched-chain alkanes and alkanes with ring structures. The presence of these isomers in a fuel helps to increase the *octane number* of a fuel, which is a measure of the tendency of a fuel to not undergo auto-ignition in an engine. *Auto-ignition* is when fuel burns spontaneously out of control. It leads to wear in the engine and wastage of petrol. The higher the octane number, the lower the tendency for a fuel to undergo auto-ignition.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 Crude oil is a mixture of hydrocarbons.

a State which two elements are present in the compounds in crude oil.

b Crude oil is separated into fractions by heating and passing the vapour into a fractionating column. Explain how the fractions separate in the column.

c Two of the fractions are gasoline and diesel. State one use of each.

d Name two fractions formed in the fractional distillation of crude oil, other than gasoline and diesel.

e Describe the differences between gasoline and diesel. In your answer you should refer to the average size of the molecules in the two liquids, the colour of the two liquids and the viscosities of the two liquids.

f One of the hydrocarbons found in the diesel fraction is $C_{18}H_{38}$. Suggest the formula of a hydrocarbon that could be found in the gasoline fraction.

SKILLS PROBLEM SOLVING

g i Write a balanced chemical equation for the complete combustion of butane, C_4H_{10}.

SKILLS REASONING

ii Incomplete combustion of hydrocarbons produces carbon monoxide. Explain why carbon monoxide is harmful to humans.

SKILLS REASONING

2 Explain why:

a burning a fuel containing sulfur as an impurity causes acid rain

b petrol engines produce oxides of nitrogen

c the presence of too much sulfur dioxide, SO_2, in the atmosphere has a damaging effect on many buildings made of marble, a form of calcium carbonate, $CaCO_3$.

SKILLS CRITICAL THINKING

3 Cracking is a process that splits larger hydrocarbons into smaller ones.

a Give two reasons why an oil company might want to crack a hydrocarbon.

b Give the conditions under which cracking is carried out.

SKILLS PROBLEM SOLVING

c A molecule of the hydrocarbon $C_{11}H_{24}$ was cracked to give two molecules of ethene, C_2H_4, and one other molecule. Write a balanced chemical equation for the reaction which took place. (You can omit the state symbols from your equation.)

d Write an equation for an alternative cracking reaction involving the same hydrocarbon, $C_{11}H_{24}$.

SKILLS CREATIVITY

4 Imagine a world in which fossil fuels such as coal, natural gas and oil had never formed. This would have effects other than the immediately obvious ones. For example, the iron and steel industry depends on coke made from coal, although in the past (on a much smaller scale) it used charcoal made from wood. Choose one aspect of the modern world and explain, in no more than 300 words, how it would be different in the absence of fossil fuels. You could choose from transport, use of materials, landscape, disease prevention, and power generation, for example, but you don't have to restrict yourself to this list.

Try not to be too simplistic about this, human beings are inventive! For example, it is possible to obtain organic chemicals from alcohol (from fermented sugar) and fuels from plant oils.

19 ALKANES

The hydrocarbons separated from the fractional distillation of crude oil are mainly alkanes. This is the simplest family of hydrocarbons, containing only carbon–carbon and carbon–hydrogen single bonds. Here we look into the structures and chemical reactions of these compounds in more detail. It is assumed that you have already read Chapter 17 (Introduction to Organic Chemistry).

LEARNING OBJECTIVES

- Know the general formula for alkanes
- Explain why alkanes are classified as saturated hydrocarbons
- Understand how to draw the structural and displayed formulae for alkanes with up to five carbon atoms in the molecule and to name the unbranched-chain isomers
- Describe the reactions of alkanes with halogens in the presence of ultraviolet radiation, limited to mono-substitution



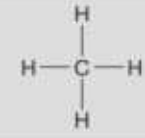
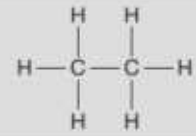
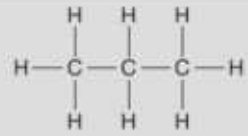
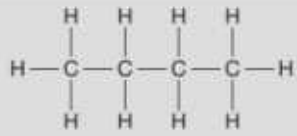
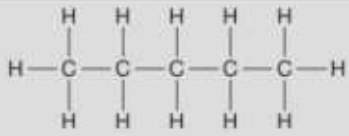
▲ Figure 19.1 The small alkanes are gases and are burned as fuels.

The alkanes are the simplest family of hydrocarbons. Hydrocarbons are compounds that contain carbon and hydrogen only.

Many of the alkanes are used as fuels. Methane is the major component of natural gas. Ethane and propane are also present in small quantities in natural gas, and are important constituents of liquefied petroleum gases (LPG) from crude oil distillation (discussed in Chapter 18).

The first five members of the alkanes series are shown in Table 19.1.

Table 19.1 Some alkanes

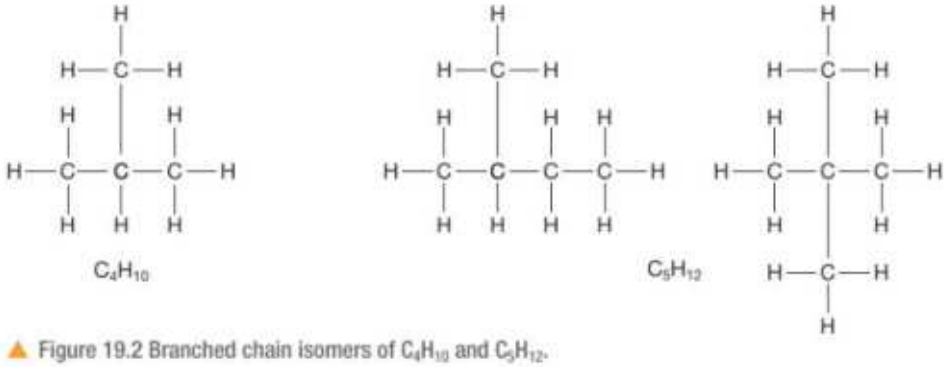
Name	Molecular formula	Structural formula	Displayed formula
methane	CH_4	CH_4	
ethane	C_2H_6	CH_3CH_3	
propane	C_3H_8	$CH_3CH_2CH_3$	
butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$	
pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	

KEY POINT

The alkanes are described as *saturated* hydrocarbons because they contain only C–C single bonds and have no double (C=C) or triple (C≡C) bonds. A way of thinking about this is that the alkanes are saturated with hydrogen, in other words they have the maximum number of hydrogen atoms possible for that number of carbon atoms. But do not write this definition down in the exam!

ISOMERS OF ALKANES

Isomers are *compounds which have the same molecular formula but different structural formulae*. The alkanes shown in Table 19.1 can all be described as *straight-chain alkanes* or as having an unbranched chain. There are also isomers of butane and pentane that have branched chains. These are shown in Figure 19.2.



▲ Figure 19.2 Branched chain isomers of C_4H_{10} and C_5H_{12}.

HOMOLOGOUS SERIES

HINT

When asked about a homologous series in the exam, it is probably best to only write about the properties (the second and third bullet points). Sometimes you do not get separate marks for 'the same functional group' and 'similar chemical properties', and perhaps a better way of writing this is 'they have similar chemical properties because they have the same functional group'.

The alkanes form a homologous series. A homologous series is a series of compounds that:

- have the same functional group
- *have similar chemical properties*
- *show a trend (gradation) in physical properties*
- can be described by the same general formula
- differ from the next by a $-CH_2-$ unit.

The alkanes form the simplest homologous series. The alkanes do not really have a functional group as they just contain single C–C and C–H bonds, which are the basis of all other organic compounds.

MEMBERS OF A HOMOLOGOUS SERIES HAVE THE SAME GENERAL FORMULA

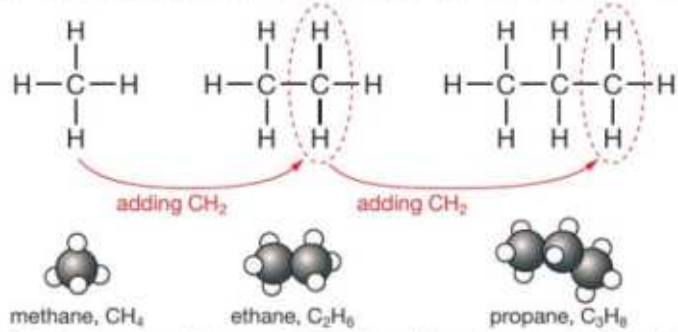
In the case of the alkanes, if there are n carbons, there are $2n + 2$ hydrogens.

The general formula for the alkanes is $\mathbf{C_nH_{2n+2}}$.

So, for example, if there are three carbons, there are $(2 \times 3) + 2 = 8$ hydrogens. The formula for propane is C_3H_8.

If you want the formula for an alkane with 15 carbons, you could work out that it is $C_{15}H_{32}$ and so on.

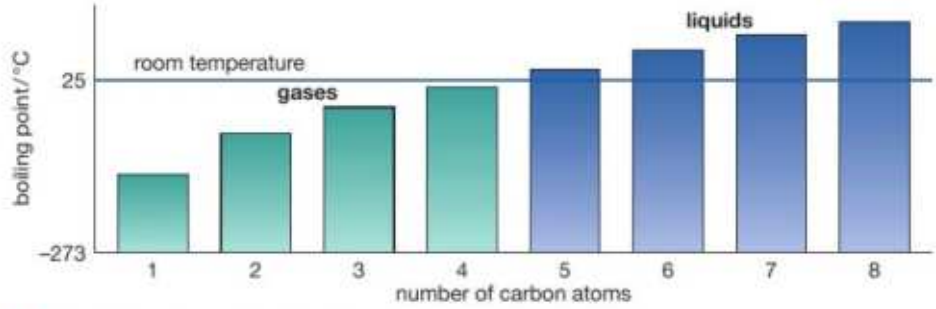
The reason that the alkanes and other homologous series can be described by a general formula is that each member differs from the next by a $-CH_2-$ unit.



▲ Figure 19.3 The three smallest alkanes. Each member differs from the next by a $-CH_2-$ unit.

MEMBERS OF A HOMOLOGOUS SERIES SHOW A TREND (GRADATION) IN PHYSICAL PROPERTIES

Figure 19.4 shows the boiling points of the first eight alkanes.



▲ Figure 19.4 Boiling points of the first eight alkanes

The first four alkanes are gases at room temperature (~25 °C). All the other alkanes you are likely to see at International GCSE are liquids. Solids start to appear at about $C_{18}H_{38}$.

The molecules of the members of a homologous series increase in size in a regular way and you can see that the *boiling points* also *increase* in a regular way.

As the molecules become bigger, the strength of the *intermolecular forces of attraction* between them *increases*. This means that *more energy* has to be put in to *break* the attractions between one molecule and its neighbours. One effect of this is that the boiling points increase in a regular way.

MEMBERS OF A HOMOLOGOUS SERIES HAVE SIMILAR CHEMICAL PROPERTIES

Chemical properties are dependent on the functional groups and bonding within the molecules. Because alkanes only contain carbon–carbon single bonds and carbon–hydrogen bonds, they are all going to behave in the same way. These are strong bonds, therefore alkanes are fairly unreactive organic compounds and are often thought of as being quite **inert**.

KEY POINT

The alkanes are not inert in the sense that they don't react with anything, like neon for example, but they are not very reactive for organic compounds and only really undergo two reactions.

TWO REACTIONS OF THE ALKANES

COMBUSTION

HINT

Don't try to learn these equations! Practise working them out for a wide range of different hydrocarbons. You will find guidance on how to work out the ethane equation in Chapter 5, page 293.

HINT

Remember, in combustion reactions it is highly unlikely that hydrogen, H_2, will be formed as a product because hydrogen is very flammable. You always obtain water, H_2O, even if there is insufficient oxygen.

All alkanes burn in air or oxygen. If there is enough oxygen, they burn *completely* to give *carbon dioxide* and *water*, for example:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$$

If there isn't enough oxygen, there is *incomplete* combustion of the hydrocarbon, and you obtain *carbon monoxide* or *carbon (soot)* instead of carbon dioxide, for example:

$$2C_2H_6(g) + 5O_2(g) \rightarrow 4CO(g) + 6H_2O(l)$$

or

$$2C_2H_6(g) + 3O_2(g) \rightarrow 4C(s) + 6H_2O(l)$$

SUBSTITUTION

Alkanes react with halogens in the presence of **ultraviolet radiation** (UV light), for example from sunlight. A hydrogen atom in the alkane is replaced by a halogen atom. This is known as a *substitution* reaction because *one atom has been replaced (or substituted) by a different one*.

EXTENSION WORK

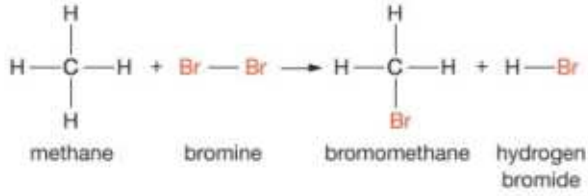
UV light is required for substitution reactions to split halogen molecules into atoms. Energy is needed to break the covalent bonds between halogen atoms. The atoms formed are called *free radicals* due to the presence of unpaired electrons on them. These are very reactive species which then go on to react with the usually unreactive alkanes.

A mixture of methane and bromine gas is orange because of the presence of the bromine. If it is exposed to sunlight, it loses its colour, and a mixture of bromomethane and hydrogen bromide gases is formed.

EXTENSION WORK

If bromine is in excess, this reaction can go on to substitute more of the hydrogens in the methane. What you obtain is a mixture of CH_3Br, CH_2Br_2, $CHBr_3$ and CBr_4, plus HBr of course. You will find out more about *multi-substitution* if you go on to do chemistry at a more advanced level.

$$CH_4(g) + Br_2(g) \rightarrow CH_3Br(g) + HBr(g)$$



▲ Figure 19.5 A substitution reaction between methane and bromine.

An exactly similar reaction happens between ethane and chlorine exposed to UV light. In this case, you get a mixture of chloroethane and hydrogen chloride gases:

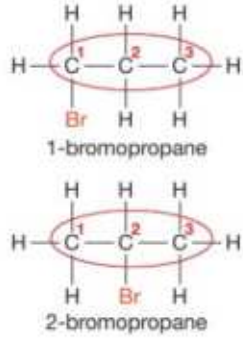
$$CH_3CH_3(g) + Cl_2(g) \rightarrow CH_3CH_2Cl(g) + HCl(g)$$

HINT

Notice the HCl(g) formed in this reaction is called hydrogen chloride rather than hydrochloric acid. To form an acid, hydrogen chloride gas must dissolve in water and dissociate to form H^+ ions (see Chapter 3).

Mono-substitution occurs when *only one hydrogen atom in the alkanes is replaced by a halogen atom*.

When propane reacts with bromine, it is possible to form two organic products even when only mono-substitution occurs. The two products are structural isomers of each other, they have the same molecular formula but different structural formulae.



▲ Figure 19.6 Two isomers of bromopropane, formed from the mono-substitution of propane with bromine.

The products formed from substitution reactions of alkanes with halogens are called *halogenoalkanes*. They are named according to the format *x-haloalkane*, where *x* indicates the position of the halogen atom in the longest carbon chain. So, when bromine reacts with propane we get 1-bromopropane and 2-bromopropane.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 a Alkanes are *saturated* hydrocarbons. Explain the term *saturated*.

b Undecane is an alkane with 11 carbon atoms.

i Write down the molecular formula for undecane.

SKILLS REASONING

ii What physical state (solid, liquid or gas) would you expect undecane to be in at room temperature (25 °C)?

SKILLS PROBLEM SOLVING

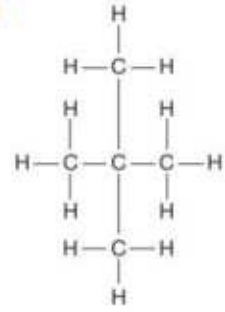
iii Write a balanced chemical equation for the complete combustion of undecane.

iv Write a balanced chemical equation for the incomplete combustion of undecane to produce carbon monoxide and explain why this reaction is harmful to humans.

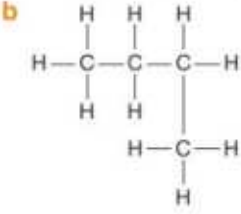
SKILLS ANALYSIS

2 Write the molecular formulae of the following compounds.

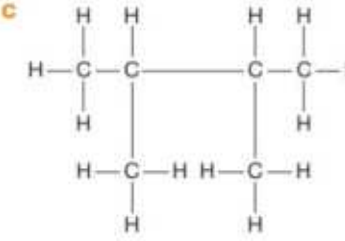
a



b



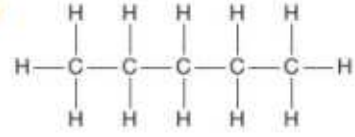
c



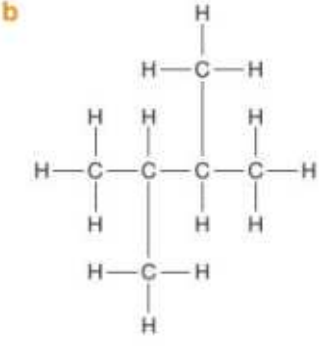
SKILLS INTERPRETATION

3 Draw two isomers of each of the following compounds.

a



b



SKILLS CRITICAL THINKING

4 Ethane reacts with bromine under certain conditions.

a State the conditions needed for this reaction to occur.

b What is the type of reaction that occurs?

SKILLS PROBLEM SOLVING

c Write a balanced chemical equation for the reaction using displayed formulae and name the organic product produced.

SKILLS INTERPRETATION

5 Butane reacts with chlorine to form two organic compounds with the formula C_4H_9Cl.

a Write a balanced chemical equation for the formation of one of these compounds.

b Draw the structures and give the names of the two possible *organic* products of this reaction.

20 ALKENES

The alkenes are another family of hydrocarbons. They all contain a carbon–carbon double bond. Alkenes can be produced from alkanes by cracking and they are much more reactive than the alkanes.



▶ Figure 20.1 Sunflower oil is polyunsaturated and contains lots of C=C groups.

LEARNING OBJECTIVES

- Know that alkenes contain the functional group >C=C<
- Know the general formula for alkenes
- Explain why alkenes are classified as unsaturated hydrocarbons
- Describe the reactions of alkenes with bromine to produce dibromoalkanes
- Describe how bromine water can be used to distinguish between an alkane and an alkene
- Understand how to draw the structural and displayed formulae for alkenes with up to four carbon atoms in the molecule, and name the unbranched-chain isomers

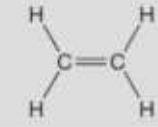
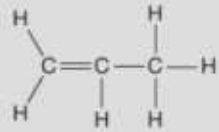
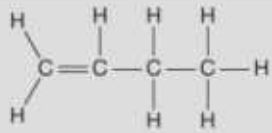
The alkenes are a homologous series of hydrocarbons which contain a carbon–carbon double bond. The **C=C** bond is the functional group of the alkenes.

The first three members of the alkene series are shown in Table 20.1.

KEY POINT

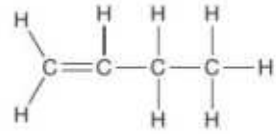
It is not possible to have an alkene with one carbon atom because alkenes must contain a C=C group so you need a minimum of two carbon atoms.

Table 20.1 The first three alkenes

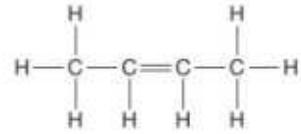
Name	Molecular formula	Empirical formula	Structural formula	Displayed formula
ethene	C_2H_4	CH_2	$CH_2=CH_2$	
propene	C_3H_6	CH_2	$CH_2=CHCH_3$	
but-1-ene	C_4H_8	CH_2	$CH_2=CHCH_2CH_3$	

ISOMERS

There are two straight-chain isomers with the formula C_4H_8:

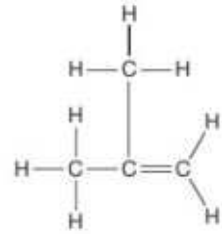


but-1-ene



but-2-ene

and one branched-chain isomer:



HINT

A way of thinking about this is that the alkenes are not saturated with H atoms, they do not have the maximum number of H atoms for that number of C atoms.

UNSATURATED HYDROCARBONS

Alkenes are ***unsaturated* compounds** because they contain a C=C bond. *A saturated compound contains single C–C bonds only whereas an unsaturated compound contains one or more double or triple C–C bonds.*

THE GENERAL FORMULA

Alkenes have the general formula $\mathbf{C_nH_{2n}}$. The number of hydrogen atoms is twice the number of carbon atoms. This means that all alkenes have the same empirical formula, CH_2.

The alkene with 11 carbon atoms will have 22 hydrogen atoms and the molecular formula $C_{11}H_{22}$.

PHYSICAL PROPERTIES

These are very similar to those of the alkanes. Remember that the small alkanes with up to four carbon atoms are gases at room temperature. The same is true for the alkenes. They are gases up to C_4H_8, and the next dozen or so are liquids. Again, the members of the homologous series *show a trend in physical properties.*

CHEMICAL REACTIONS OF THE ALKENES

COMBUSTION

In common with all hydrocarbons, alkenes burn in air or oxygen to give carbon dioxide and water, for example:

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$$

This isn't a reaction anybody would ever choose to do. Alkenes are much too useful to waste by burning them.

ADDITION

The C=C double bond is the functional group. The functional group determines the chemical properties of a compound. Alkenes have characteristic chemical properties which are different from those of alkanes. Alkenes are much more reactive than alkanes.

Alkenes undergo addition reactions. Part of the double bond breaks to become a single C–C bond and the electrons are used to join other atoms onto the two carbon atoms.

THE ADDITION OF BROMINE

Bromine adds to alkenes without any need for heat, light or a catalyst. The reaction is often carried out using bromine water (aqueous bromine solution) as, for example, in Figure 20.2, with ethene.

HINT

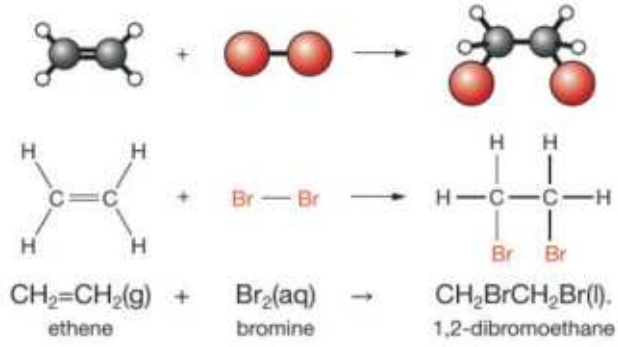
Decode the name and make sure you can see how it works. 'eth' shows a two-carbon chain. 'ane' shows only carbon–carbon single bonds. The beginning of the name, '1,2-dibromo', shows two bromine atoms attached to the first and second carbon atoms.

You know a reaction has happened because bromine water is *orange* but the product, called 1,2-dibromoethane, is a *colourless* liquid.

You can write this as an equation in two ways: first, using displayed formulae and second, using structural formulae.

HINT

Make sure you can see how these formulae relate to the full structures in the equation above.



▲ Figure 20.2 An addition reaction: an alkene plus bromine

THE TEST FOR UNSATURATED COMPOUNDS

Any compound with a carbon–carbon double bond will react with bromine in a similar way to ethene. This is used to *test for a carbon–carbon double bond*. If you shake an unknown organic compound with bromine water and the orange bromine water is *decolourised* (the colour changes from orange to colourless), the compound contains a carbon–carbon double bond. If your unknown compound is a gas, you can simply bubble it through bromine water with the same effect.

HINT

You must be careful with the words you use here: the final mixture is *colourless* and not clear. Do not use the word clear. Clear means not cloudy, you can see through it. The bromine water is clear and any other solution can also be described as clear.

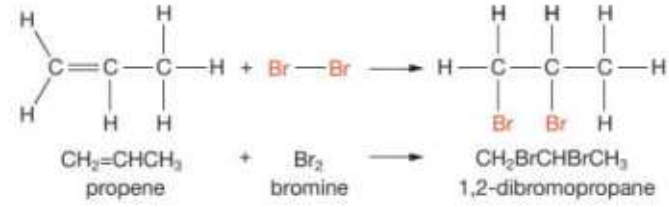
The left-hand tube in Figure 20.3 shows the effect of shaking a liquid alkene with bromine water. The organic layer (containing the alkene) is on top. You can see that the bromine water has been completely decolourised, showing the presence of the carbon–carbon double bond.



▲ Figure 20.3 The result of shaking a liquid alkene (left) or alkane (right) with bromine water.

The right-hand tube in Figure 20.3 shows what happens if you use a liquid alkane, which doesn't have a carbon–carbon double bond. The colour of the bromine is still there. Alkanes do not decolourise bromine water because they do not contain a carbon–carbon double bond.

The addition reaction between bromine and propene is very similar to that of ethene. Part of the carbon–carbon double bond breaks and two bromine atoms add across the bond, as shown in Figure 20.4.



▲ Figure 20.4 An addition reaction of propene with bromine

The product is called 1,2-dibromopropane. Its structure is based on propane and the prefix '1,2-dibromo' shows there are two bromine atoms, on the first and the second carbon atoms.

OTHER IMPORTANT ADDITION REACTIONS OF ALKENES

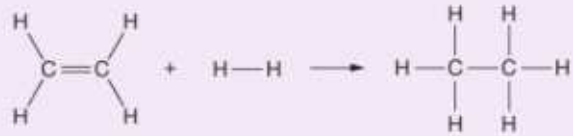


▲ Figure 20.5 Production of margarine

EXTENSION WORK

Hydrogenation

A **hydrogenation** reaction involves the *addition of hydrogen*. An alkene reacts with hydrogen to form an alkane, for example:



$CH_2{=}CH_2 + H_2 \rightarrow CH_3CH_3$

This reaction is used for the production of margarine, which is made by hydrogenation of polyunsaturated (i.e. many C=C bonds) plant oils.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 The alkenes are a *homologous series* of *unsaturated* hydrocarbons.

a i State two characteristics of the members of a *homologous series*.

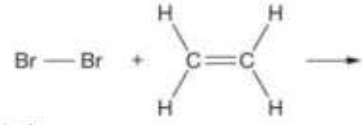
ii Explain the term *unsaturated*.

b Ethene is the simplest member of the alkenes. Bromine water can be used to distinguish alkenes from alkanes.

i Bromine water is added to ethene. State the starting colour of the bromine water and the finishing colour of the reaction mixture.

SKILLS PROBLEM SOLVING, INTERPRETATION

ii Complete the equation by drawing and naming the displayed formula of the product.



Name of the product:

SKILLS INTERPRETATION

c Isomers are compounds that have the same molecular formula but different displayed formulae. Draw the displayed formulae of three alkene isomers that have the molecular formula C_4H_8.

d Can you draw any other isomers of C_4H_8 which are *not* alkenes?

SKILLS CRITICAL THINKING

2 A gaseous hydrocarbon, **P**, with three carbon atoms, decolourises bromine water.

a Explain what the decolorisation of the bromine water tests for.

b Write the displayed formula for the hydrocarbon.

SKILLS PROBLEM SOLVING

c Write a balanced chemical equation for the reaction between the hydrocarbon and bromine, using displayed formulae.

d The reaction between ethane and bromine gas in the presence of UV light also causes the bromine to lose colour.

i Write a balanced chemical equation for this reaction.

SKILLS REASONING

ii This reaction is described as a substitution reaction, whereas the reaction between **P** and bromine is an addition reaction. Using the equations you have already written, explain the difference between addition and substitution.

SKILLS CRITICAL THINKING

3 Alkenes undergo addition reactions.

a Predict the structural formula of the compound formed when chlorine reacts with propene. Name the product formed.

b Ethene reacts with hydrogen. Give the name and structural formula of the product.

4 Propene can be made by heating propane and sulfur.

a Name another method of making propene and state two conditions for making alkenes from alkanes.

SKILLS EXECUTIVE FUNCTION

b Describe a chemical test which can be used to distinguish between propane and propene.

Test:

Result with propane:

Result with propene:

SKILLS CRITICAL THINKING

5 Give the structural formulae and names of the product when but-1-ene reacts with each of the following:

a steam

b hydrogen chloride (HCl)

c bromine.

21 SYNTHETIC POLYMERS

Polymers are everywhere, ranging from naturally occurring polymers, for example proteins (polypeptides) and sugar (polysaccharides), which you probably have met before, to synthetic polymers used for plastic bags and clothing. Polymers are large molecules consisting of many repeating units. This chapter looks at one way that polymers can be made: addition polymerisation for polymers such as poly(ethene) and PVC.





▲ Figure 21.1 Synthetic polymers are extremely useful for making a variety of products, from the coating for electrical wires to plastic bottles and intelligent label chips.

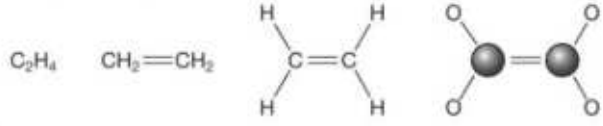
LEARNING OBJECTIVES

- Know that an addition polymer is formed by joining up many small molecules called monomers
- Understand how to draw the repeat unit of an addition polymer, including poly(ethene), poly(propene), poly(chloroethene) and poly(tetrafluoroethene)
- Understand how to deduce the structure of a monomer from the repeat unit of an addition polymer and vice versa
- Explain problems in the disposal of addition polymers, including:
  - their inertness and inability to biodegrade
  - the production of toxic gases when they are burned

ADDITION POLYMERISATION

THE POLYMERISATION OF ETHENE

Ethene is the smallest alkene and can be produced by cracking. It is the smallest hydrocarbon containing a carbon–carbon double bond. Figure 21.2 shows different ways of representing an ethene molecule.



▲ Figure 21.2 Ethene

Under the right conditions, molecules containing carbon–carbon double bonds can join together to produce very long chains. Part of the double bond is broken to become a single bond, and the electrons in it are used to join to neighbouring molecules.

Polymerisation *is the joining up of lots of little molecules* (**monomers**) *to make one big molecule* (**polymer**). In the case of ethene, lots of ethene molecules join together to make *poly(ethene)*, which is more usually called *polythene*. *Molecules simply add onto each other without anything else being formed*. This is called **addition polymerisation**.

KEY POINT

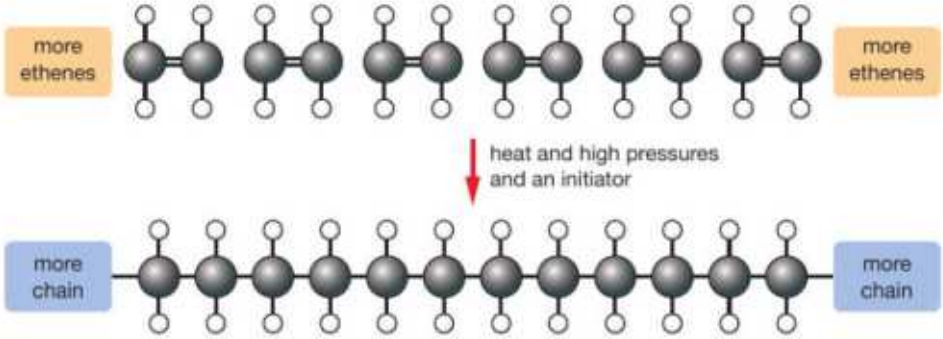
An *initiator* is used to start the process. You mustn't call it a catalyst because it is consumed in the reaction.

EXTENSION WORK

People occasionally wonder what happens at the ends of the chains. They don't end tidily! Bits of the initiator are bonded on at either end. You don't need to worry about that for International GCSE.

KEY POINT

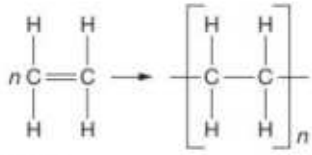
In this structure for poly(ethene) *n* represents a large but variable number. It simply means that the structure in the brackets (called the *repeat unit*) repeats itself many times in the molecule. When representing a polymer, the bonds on the two sides of the repeat unit should extend outside the square brackets to show that the carbon atoms are joined to the next ones in a chain, as shown in Figure 21.4.



▲ Figure 21.3 The polymerisation of ethene

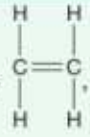
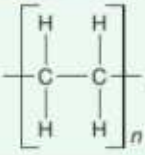
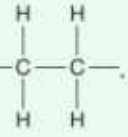
The chain length can vary from about 4000 to 40 000 carbon atoms.

For normal purposes, the polymerisation reaction is written using displayed formulae.



▲ Figure 21.4 Formation of poly(ethene)

HINT

Make sure you can distinguish between the different terms monomer, polymer and **repeat unit**. In the equation in Figure 21.4, the monomer is , the polymer is  and the repeat unit is .

USES FOR POLY(ETHENE)

KEY POINT

Although the polymer is called *poly(ethene)* it is actually an *alkane*. The polymer is saturated and will not decolourise bromine water.

Poly(ethene) comes in two types: low-density poly(ethene) (LDPE) and high-density poly(ethene) (HDPE). Low-density poly(ethene) is mainly used as a thin film to make polythene bags. It is very flexible and not very strong.

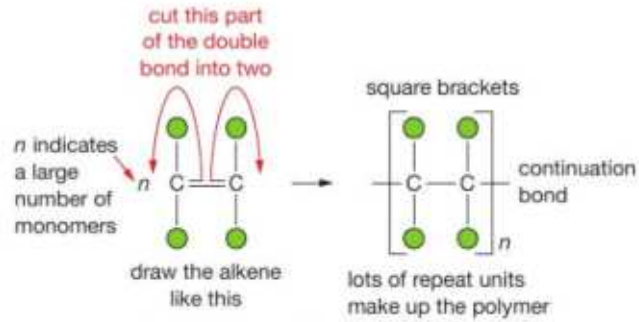


▲ Figure 21.5 Plastic bags made from poly(ethene)

High-density poly(ethene) is used where greater strength and rigidity are needed, for example to make plastic bottles such as milk bottles. If you can find a recycling symbol with the letters HDPE next to it, then the bottle is made of high-density poly(ethene). If it has some other letters there, then it is made of a different polymer.

HOW TO DEDUCE THE POLYMERISATION REACTION FOR ANY ALKENE

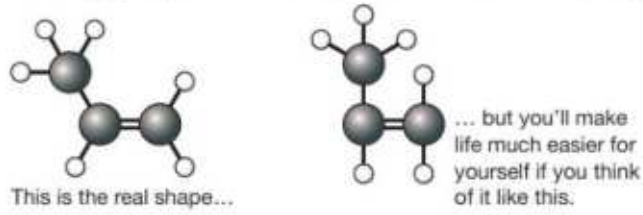
Figure 21.6 shows how to work out a polymerisation reaction starting from any alkene. The key thing is to always draw the alkene as shown with just the C=C in the middle.



▲ Figure 21.6 How to work out a polymerisation reaction

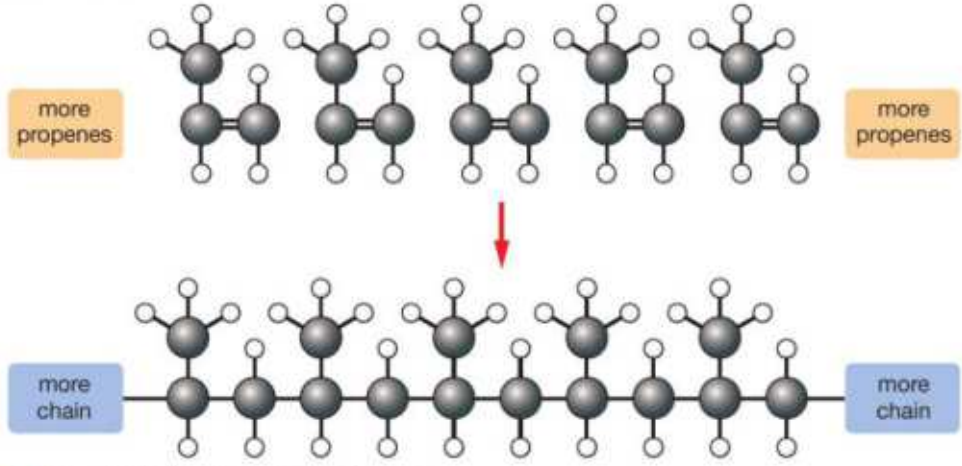
THE POLYMERISATION OF PROPENE

Propene is another alkene, this time with three carbon atoms in each molecule. Its formula is normally written as $CH_3CH=CH_2$. Think of it as a modified ethene molecule, with a CH_3 group attached in place of one of the hydrogen atoms.



▲ Figure 21.7 Propene

When propene is polymerised you obtain *poly(propene)*. This used to be called *polypropylene*.

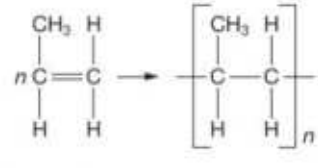


▲ Figure 21.8 The polymerisation of propene

HINT

When you draw an addition polymerisation reaction never change anything except opening out the double bond and drawing the continuation bonds on each side.

Write this as:



▲ Figure 21.9 Formation of poly(propene)

USES OF POLY(PROPENE)

Poly(propene) is somewhat stronger than poly(ethene). It is used to make ropes and crates (among many other things). If an item has a recycling mark with PP inside it or near it, it is made of poly(propene).



▲ Figure 21.10 PP recycling symbol



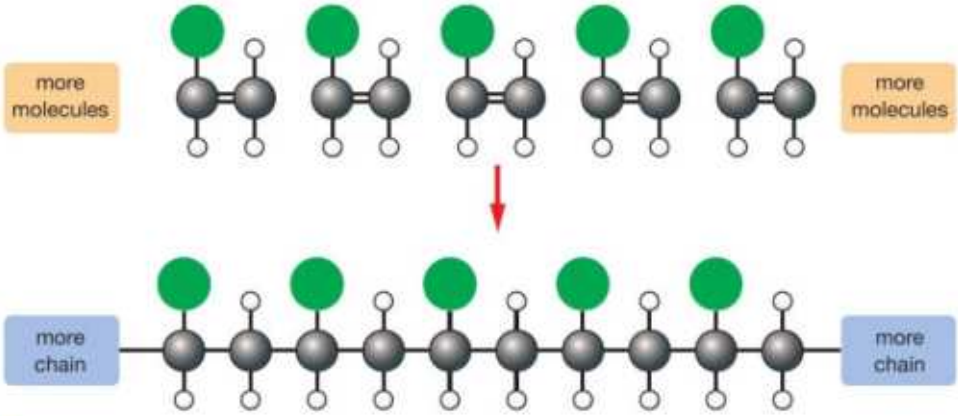
▲ Figure 21.11 Poly(propene) is used to make crates . . .



▲ Figure 21.12 . . . and ropes.

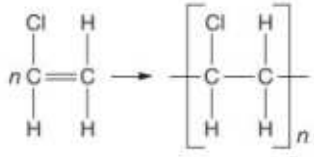
THE POLYMERISATION OF CHLOROETHENE

Chloroethene is a molecule in which one of the hydrogen atoms in ethene is replaced by a chlorine. Its formula is CH_2=CHCl. In the past, it was called vinyl chloride. Polymerising chloroethene gives you *poly(chloroethene)*. This is usually known by its old name, polyvinylchloride or PVC.



▲ Figure 21.13 The polymerisation of chloroethene

Write this as:



▲ Figure 21.14 Formation of poly(chloroethene)

HINT

When you draw this, it isn't important whether you put the chlorine atom on the left-hand carbon atom or the right-hand one.

USES OF POLY(CHLOROETHENE)

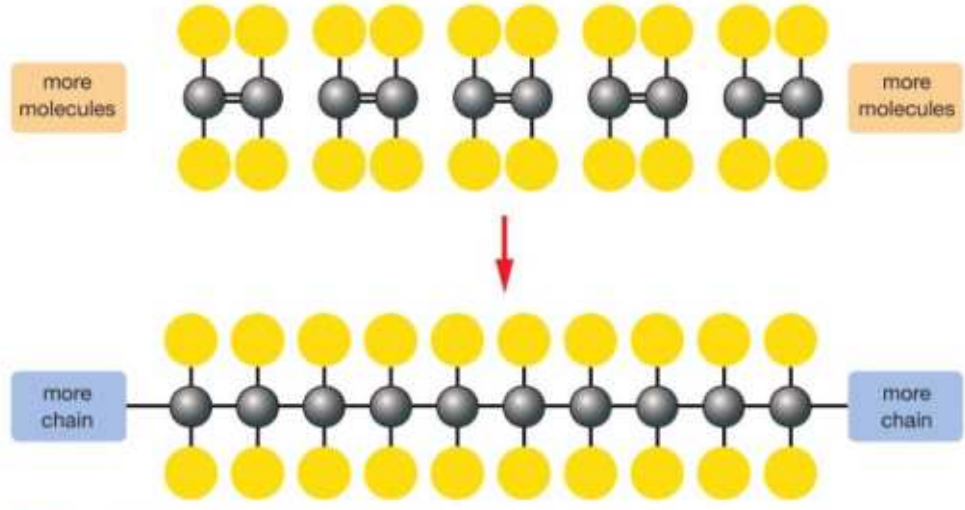
Poly(chloroethene), known as PVC, has a lot of uses. It is quite strong and rigid, and so can be used for water pipes or replacement windows. It can also be made flexible by adding *plasticisers*. This makes it useful for sheet floor coverings, and even clothing. These polymers don't conduct electricity, therefore PVC can be used for electrical insulation.



▲ Figure 21.15 PVC has a variety of uses.

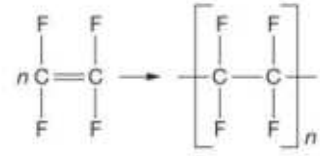
THE POLYMERISATION OF TETRAFLUOROETHENE

Tetrafluoroethene is another molecule derived from ethene in which all four hydrogen atoms are replaced by fluorine. Its formula is $CF_2=CF_2$. Polymerising tetrafluoroethene gives you poly(tetrafluoroethene) or PTFE, more commonly known as Teflon®.



▲ Figure 21.16 The polymerisation of tetrafluoroethene

Write this as:



▲ Figure 21.17 Formation of poly(tetrafluoroethene)

KEY POINT

If you look at this reaction, you can see it is exactly the same as the polymerisation of ethene except that each H has been replaced by an F.

USES OF POLY(TETRAFLUOROETHENE)

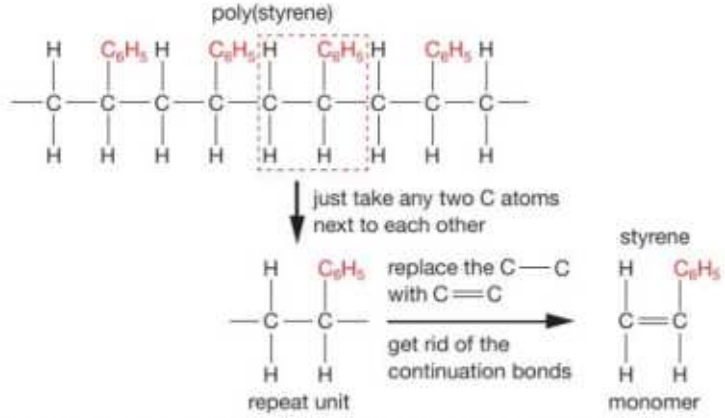
Poly(tetrafluoroethene) is often used as a non-stick coating for pots and pans. It is very unreactive due to the strong carbon–fluorine bonds, and can be found lining containers for corrosive chemicals.



▲ Figure 21.18 PTFE is used for non-stick coatings.

WORKING OUT THE MONOMER FOR A GIVEN ADDITION POLYMER

In an exam you may find that you are given the structure of a polymer and asked to deduce what the repeat unit is or what monomer it was made from. Figure 21.19 shows you how to do this.



▲ Figure 21.19 How to work out the repeat unit and monomer for poly(styrene)

The C_6H_5 group is complicated, but we don't need to worry about that when we write the structure of the monomer; work from the structure you are given. First find the repeat unit, which can be done simply by taking any two adjacent carbon atoms in the main polymer chain. To derive the monomer, a double bond needs to be put back between the two middle carbon atoms of the repeat unit.

DISPOSAL OF ADDITION POLYMERS

Recycling of plastics is important, not just to save raw materials, but because it takes a very long time for addition polymers like poly(ethene) and poly(chloroethene) to break down in the environment. They contain strong covalent bonds, making them essentially *inert* at ordinary temperatures. They are **non-biodegradable**, meaning *they cannot be broken down by bacteria in the environment*.

One solution to the problem of their disposal is to *bury them in landfill sites*, which are basically just big holes in the ground, where they will remain unchanged for thousands of years.



▲ Figure 21.20 Plastics (and other rubbish) can be disposed of in landfill sites.

Some countries, including Denmark and Japan, *incinerate (burn) plastics* in order to tackle the problem of disposal. This releases a lot of heat energy, which can be used to generate electricity. However, there are problems associated with this. For example, carbon dioxide is produced, which contributes to **global warming**. Toxic gases are also released, including carbon monoxide and hydrogen chloride.

There are advantages and disadvantages for using either method to dispose of plastics.

Disposal method	Advantages	Disadvantages
Landfill	No greenhouse gases or toxic gases produced from plastics Cheap	Ugly, smelly and noisy; no one wants to live next to a landfill site Uses large areas of land The waste will be there for thousands of years
Incineration	Requires little space Can produce heat for local homes/offices and/or produce electricity	It is expensive to build and maintain the plant Produces greenhouse gases Releases toxic gases The ash produced must still be disposed of in landfill sites

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING

1 Ethene, C_2H_4, is an important molecule used in industry. It is an *unsaturated hydrocarbon*.

a Explain the terms *unsaturated* and *hydrocarbon*.

SKILLS PROBLEM SOLVING

b Ethene burns easily and releases a large amount of heat during combustion. Write a balanced chemical equation for the complete combustion of ethene.

SKILLS REASONING

c Explain why in industry ethene is considered too valuable to be used as a fuel.

SKILLS CRITICAL THINKING

2 Propene, C_3H_6, can be polymerised to make poly(propene).

a Explain the term *polymerisation*.

SKILLS INTERPRETATION

b Draw a displayed formula for propene.

c Draw a diagram to represent the structure of a poly(propene) chain showing three repeat units.

SKILLS CRITICAL THINKING

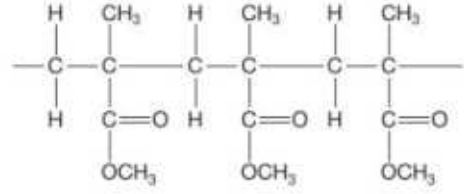
d The formation of poly(propene) is an example of *addition* polymerisation. Explain what is meant by the word *addition*.

SKILLS PROBLEM SOLVING

e Styrene has the formula $C_6H_5CH{=}CH_2$. Write a balanced chemical equation to show what happens when styrene is polymerised to make polystyrene. Your equation should clearly show the structure of the polystyrene. (Show the C_6H_5 group as a whole.)

SKILLS INTERPRETATION

f A small part of a Perspex molecule looks like this:



Draw the structure of the monomer from which Perspex is made.

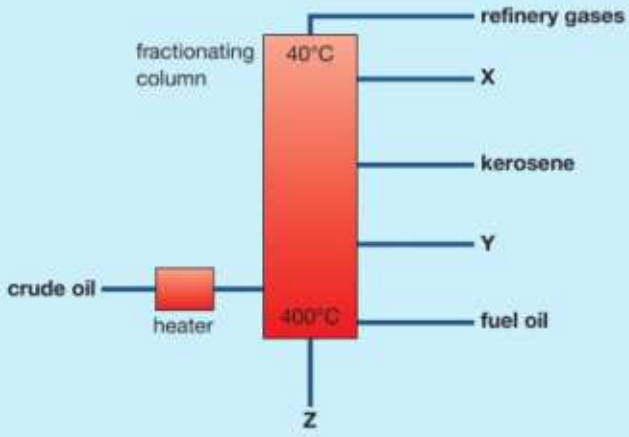
SKILLS DECISION MAKING

g Many addition polymers, for example those used for making plastic bags, are not biodegradable. Used plastic bags can be either buried underground in landfill sites or incinerated. State which method of disposal you think is better and give two reasons for your choice.

UNIT QUESTIONS

SKILLS ANALYSIS

1 Crude oil is a complex mixture of hydrocarbons. The diagram shows the separation of crude oil into simpler mixtures called fractions.



a What could X, Y and Z represent (choose one answer)? **(1)**

	X	Y	Z
A	gasoline	bitumen	diesel
B	diesel	gasoline	bitumen
C	bitumen	gasoline	diesel
D	gasoline	diesel	bitumen

SKILLS CRITICAL THINKING

b State a use for the refinery gas fraction. **(1)**

c Name the liquid that leaves the fractionating column at the lowest temperature. **(1)**

d Describe how crude oil is separated into fractions in industry. **(4)**

e Write down and explain the relationship between the number of carbon atoms in a hydrocarbon and its boiling point. **(2)**

SKILLS PROBLEM SOLVING

f One of the hydrocarbons, $C_{15}H_{32}$, called pentadecane, is present in the kerosene fraction. It could be used as a fuel in jet engines. Write an equation for the incomplete combustion of pentadecane to produce carbon monoxide. **(2)**

g The complete combustion of alkanes produces carbon dioxide, CO_2, which can dissolve in water to form a weakly acidic solution.

SKILLS INTERPRETATION

i Draw a dot-and-cross diagram to show the bonding in CO_2. Show the outer electrons only. **(2)**

SKILLS REASONING

ii Predict the most likely pH of a solution of CO_2 (choose one answer). **(1)**

A 1 **B** 5 **C** 7 **D** 9

SKILLS CRITICAL THINKING 6th

h $C_{15}H_{32}$ is a member of the alkane family. Long-chain alkanes are often cracked to form alkenes.

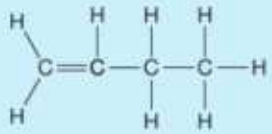
i Write down two conditions used for cracking alkanes in industry. **(2)**

ii Give two reasons why cracking is necessary in the oil industry. **(2)**

7th **iii** During cracking, one molecule of $C_{15}H_{32}$ is converted into one molecule of ethene, one molecule of another alkene C_4H_8 and one molecule of hydrocarbon **W**. State the molecular formula of **W**. **(1)**

6th **iv** Alkenes are unsaturated hydrocarbons. Write down what is meant by the term *unsaturated*. **(1)**

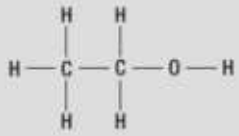
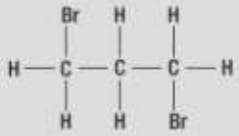
SKILLS INTERPRETATION 8th **v** One possible structure for C_4H_8 is



Draw a displayed formula for each of the other two isomers of C_4H_8, which are also alkenes. **(2)**

(Total 22 marks)

SKILLS ANALYSIS 6th **2** The table shows the formulae of some organic compounds.

A	B	C
$CH_2=CHCl$	$CH_3CH_2CH_3$	$CH_2=CHCH_2CH_3$
D	E	F
C_2H_6		

a Give one reason why compound **E** is *not* a hydrocarbon. **(1)**

b **i** State the name of compound **F**. **(1)**

SKILLS INTERPRETATION 8th **ii** Draw the displayed formula of an isomer of compound **F**. **(2)**

SKILLS PROBLEM SOLVING **c** Compound **C** can undergo an addition reaction with bromine. Complete the equation below showing the structural formula of the product(s). **(1)**

$CH_2=CHCH_2CH_3 + Br_2 \rightarrow$

d Two of the compounds shown belong to the same homologous series.

SKILLS CRITICAL THINKING 6th **i** Give the letters of these two compounds. **(1)**

ii Write down the general formula of this homologous series. **(1)**

iii Write down *two* other characteristics of the compounds in a homologous series. **(2)**

e Compound **A** can undergo addition polymerisation.

i Give the name of the addition polymer formed by compound **A**. **(1)**

7th **ii** Draw the repeat unit of the addition polymer of compound **A**. **(1)**

SKILLS REASONING

iii Explain the problems in the disposal of the addition polymer formed by compound **A**. **(2)**

iv Write down and explain the observations you would make if bromine water was added to the addition polymer of **A**. **(2)**

SKILLS CRITICAL THINKING

f Compound **B** undergoes a reaction with chlorine.

i Write down the condition required for this reaction to take place. **(1)**

ii Write down the type of reaction that occurs. **(1)**

SKILLS INTERPRETATION

iii Draw the displayed formulae for the two possible organic products from the reaction between compound **B** and chlorine. **(2)**

(Total 19 marks)

SKILLS PROBLEM SOLVING

3 Compound **X** contains 55% carbon, 9% hydrogen and 36% oxygen by mass.

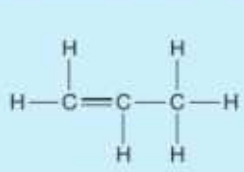
a Calculate the empirical formula of **X**. **(3)**

b The relative molecular mass (M_r) of **X** is 88. Deduce the molecular formula of **X**. **(1)**

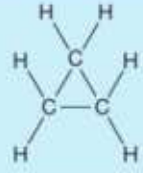
(Total 4 marks)

SKILLS EXECUTIVE FUNCTION

4 Below are two hydrocarbons with the molecular formula C_3H_6.



compound 1



compound 2

a Describe a chemical test for distinguishing between the two hydrocarbons and give the results for this test. **(3)**

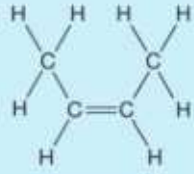
Test:

Result with compound 1:

Result with compound 2:

SKILLS CRITICAL THINKING

b Compound 3 is in the same homologous series as compound 1. Compound 3 can form an addition polymer. Draw the repeat unit of this polymer.



compound 3 **(2)**

c Name the addition polymer formed by compound 3. **(1)**

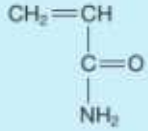
(Total 6 marks)

SKILLS INTERPRETATION

5 This question is about addition polymers.

a Poly(propene) is an addition polymer made from propene $CH_2{=}CHCH_3$. Draw a length of the poly(propene) chain showing two repeat units. **(2)**

b Another addition polymer, polyacrylamide, is used to make hydrogel in contact lenses, nappies and drug delivery systems. The structure of the polymer is shown in the diagram. Draw the structural formula of the monomer used to make polyacrylamide.



(1)

(Total 3 marks)

MOVEMENT AND POSITION 489 | FORCES AND SHAPE 504 | FORCES AND MOVEMENT 514

PHYSICS UNIT 1 FORCES AND MOTION

Forces make things move, like this Atlas V rocket carrying the Cygnus spacecraft up to the International Space Station. Forces hold the particles of matter together and keep us on the Earth. Forces can make things slow down. This is useful when we apply the brakes when driving a car! Forces can change the shape of things, sometimes temporarily and sometimes permanently. Forces make things rotate and change direction.



1 MOVEMENT AND POSITION

It is very useful to be able to make predictions about the way moving objects behave. In this chapter you will learn about some equations of motion that can be used to calculate the speed and acceleration of objects, and the distances they travel in a certain time.





▲ Figure 1.1 The world is full of speeding objects.

LEARNING OBJECTIVES

- Plot and explain distance–time graphs
- Know and use the relationship between average speed, distance moved and time taken:

  $$\text{average speed} = \frac{\text{distance moved}}{\text{time taken}}$$
- Practical: investigate the motion of everyday objects such as toy cars or tennis balls
- Know and use the relationship between acceleration, change in velocity and time taken:

  $$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}} \qquad a = \frac{(v - u)}{t}$$
- Plot and explain velocity–time graphs
- Determine acceleration from the gradient of a velocity–time graph
- Determine the distance travelled from the area between a velocity–time graph and the time axis
- Use the relationship between final speed, initial speed, acceleration and distance moved:

  (final speed)^2 = (initial speed)^2 + (2 × acceleration × distance moved)

  $v^2 = u^2 + (2 \times a \times s)$

KEY POINT

Sometimes average speed is shown by the symbols $v_{average}$ or $\bar{v}$ but in this book v will be used.

UNITS

In this section you will need to use kilogram (kg) as the unit of mass, metre (m) as the unit of length, and second (s) as the unit of time, You will find measurements of mass made in subdivisions of the kilogram, like grams (g) and milligrams (mg), measurements of length in multiples of the metre, like the kilometre (km), and subdivisions like the centimetre (cm) and millimetre (mm). You will also be familiar with other units for time: minutes, hours, days and years etc. You will need to take care to convert units in calculations to the base units of kg, m and s when you meet these subdivisions and multiples.

Other units come from these base units. In the first chapter you will meet the units for:

- speed and velocity: metre per second (m/s)
- acceleration: metre per second squared (m/s^2).

In later chapters you will meet the units for:

- force: newton (N)
- gravitational field strength: newton per kilogram (N/kg)

Speed is a term that is often used in everyday life. Action films often feature high-speed chases. Speed is a cause of fatal accidents on the road. Sprinters aim for greater speed in competition with other athletes. Rockets must reach a high enough speed to put communications satellites in **orbit** around the Earth. This chapter will explain how speed is defined and measured and how distance–time graphs are used to show the movement of an object as time passes. We shall then look at changing speed – **acceleration** and **deceleration**. We shall use velocity–time graphs to find the acceleration of an object. We shall also find how far an object has travelled using its velocity–time graph. You will find out about the difference between speed and velocity on page 492.

AVERAGE SPEED

A car travels 100 kilometres in 2 hours so the average speed of the car is 50 km/h. You can work this out by doing a simple calculation using the following definition of speed:

$$\text{average speed, } v = \frac{\text{distance moved, } s}{\text{time taken, } t}$$

$$v = \frac{s}{t}$$

The average speed of the car during the journey is the total distance travelled, divided by the time taken for the journey. If you look at the speedometer in a car you will see that the speed of the car changes from instant to instant as the accelerator or brake is used. The speedometer therefore shows the instantaneous speed of the car.

KEY POINT

Sometimes you may see '*d*' used as the symbol for distance travelled, but in this book '*s*' will be used to be consistent with the symbol used in A level maths and physics.

UNITS OF SPEED

Typically the distance moved is measured in metres and time taken in seconds, so the speed is in metres per second (m/s). Other units can be used for speed, such as kilometres per hour (km/h), or centimetres per second (cm/s). In physics the units we use are **metric**, but you can measure speed in miles per hour (mph). Many cars show speed in both mph and kilometres per hour (kph or km/h). Exam questions should be in metric units, so remember that m is the abbreviation for metres (and not miles).

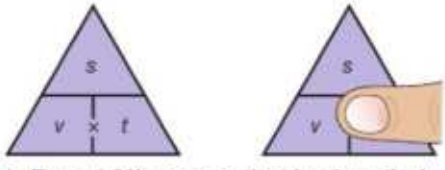
REARRANGING THE SPEED EQUATION

If you are given information about speed and time taken, you will be expected to rearrange the speed equation to make the distance moved the subject:

$$\text{distance moved, } s = \text{average speed, } v \times \text{time, } t$$

and to make the time taken the subject if you are given the distance moved and speed:

$$\text{time taken, } t = \frac{\text{distance moved, } s}{\text{average speed, } v}$$



▲ Figure 1.2 You can use the triangle method for rearranging equations like $s = v \times t$.

REMINDER

To use the triangle method to rearrange an equation, cover up the part of the triangle that you want to find. For example, in Figure 1.2, if you want to work out how long (t) it takes to move a distance (s) at a given speed (v), covering t in Figure 1.2 leaves $\frac{s}{v}$, or distance divided by speed. If an examination question asks you to write out the equation for calculating speed, distance or time, always give the actual equation (such as $s = v \times t$). You may not get the mark if you just draw the triangle.

SPEED TRAP!



▲ Figure 1.3 A stopwatch will measure the time taken for the vehicle to travel the distance.

Suppose you want to find the speed of cars driving down your road. You may have seen the police using a mobile speed camera to check that drivers are keeping to the speed limit. Speed guns use microprocessors (computers on a 'chip') to produce an instant reading of the speed of a moving vehicle, but you can conduct a very simple experiment to measure car speed.

Measure the distance between two points along a straight section of road with a tape measure or 'click' wheel. Use a stopwatch to measure the time taken for a car to travel the measured distance. Figure 1.4 shows you how to operate your 'speed trap'.

1. Measure 50 m from a start point along the side of the road.
2. Start a stopwatch when your partner signals that the car is passing the start point.
3. Stop the stopwatch when the car passes you at the finish point.



▲ Figure 1.4 How to measure the speed of cars driving on the road

Safety note: No measurements should be taken on the public road or pavement but it is possible to do so within the school boundary within sight of the road.

KEY POINT

You can convert a speed in m/s into a speed in km/h.

If the car travels 12.8 metres in one second it will travel

12.8 × 60 metres in 60 seconds (that is, one minute) and

12.8 × 60 × 60 metres in 60 minutes (that is, 1 hour), which is

46 080 metres in an hour or 46.1 km/h (to one decimal place).

We have multiplied by 3600 (60 × 60) to convert from m/s to m/h, then divided by 1000 to convert from m/h to km/h (as there are 1000 m in 1 km).

Rule: to convert m/s to km/h simply multiply by 3.6.

Using the measurements made with your speed trap, you can work out the speed of the car. Use the equation:

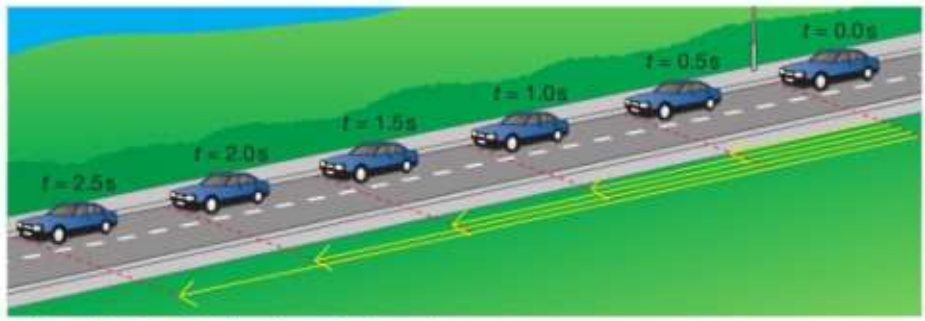
$$\text{average speed, } v = \frac{\text{distance moved, } s}{\text{time taken, } t}$$

So if the time measured is 3.9 s, the speed of the car in this experiment is:

$$\text{average speed, } v = \frac{50\,\text{m}}{3.9\,\text{s}}$$

$$= 12.8\ \text{m/s}$$

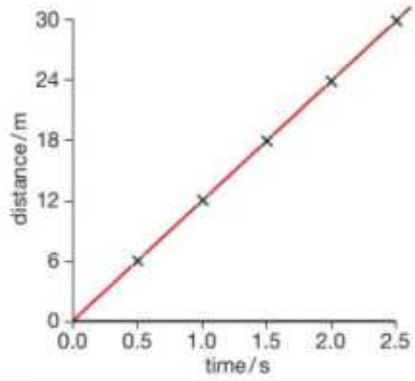
DISTANCE–TIME GRAPHS



▲ Figure 1.5 A car travelling at constant speed

Figure 1.5 shows a car travelling along a road. It shows the car at 0.5 second intervals. The distances that the car has travelled from the start position after each 0.5 s time interval are marked on the picture. The picture provides a record of how far the car has travelled as time has passed. The table below shows the data for this car. You will be expected to plot a graph of the distance travelled (**vertical** axis) against time (horizontal axis) as shown in Figure 1.6.

Time from start / s	0.0	0.5	1.0	1.5	2.0	2.5
Distance travelled from start / m	0.0	6.0	12.0	18.0	24.0	30.0



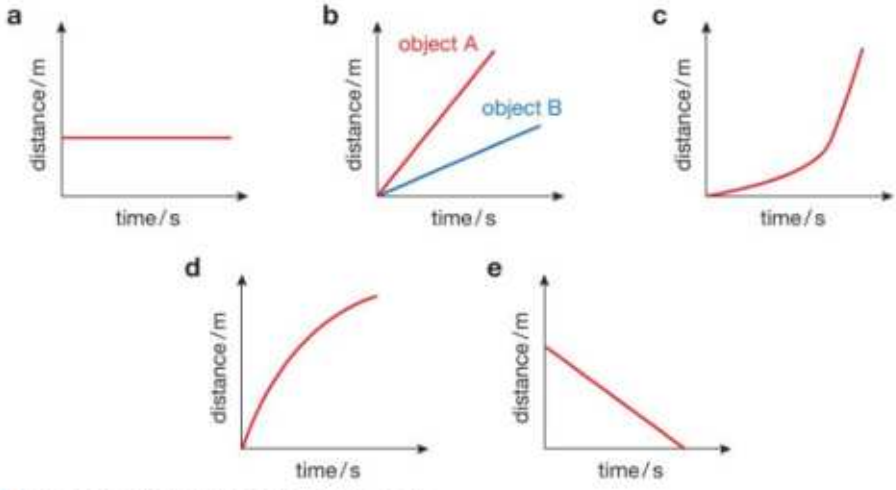
▲ Figure 1.6 Distance–time graph for the travelling car in Figure 1.5

The distance–time graph tells us about how the car is travelling in a much more convenient form than the series of drawings in Figure 1.5. We can see that the car is travelling equal distances in equal time intervals – it is moving at a steady or constant speed. This fact is shown immediately by the fact that the graph is a straight line. The slope or **gradient** of the line tells us the speed of the car – the steeper the line the greater the speed of the car. So in this example:

$$\text{speed} = \text{gradient} = \frac{\text{distance}}{\text{time}} = \frac{30\,\text{m}}{2.5\,\text{s}} = 12\,\text{m/s}$$

KEY POINT

A curved line on distance–time graphs means that the speed or velocity of the object is changing. To find the speed at a particular instant of time we would draw a tangent to the curve at that instant and find the gradient of the tangent.



▲ Figure 1.7 Examples of distance–time graphs

In Figure 1.7a the distance is not changing with time – the line is horizontal. This means that the speed is zero. In Figure 1.7b the graph shows how two objects are moving. The red line is steeper than the blue line because object A is moving at a higher speed than object B. In Figure 1.7c the object is speeding up (**accelerating**) shown by the graph line getting steeper (gradient getting bigger). In Figure 1.7d the object is slowing down (decelerating).

THE DIFFERENCE BETWEEN SPEED AND VELOCITY

Some displacement–time graphs look like the one shown in Figure 1.7e. It is a straight line, showing that the object is moving with constant speed, but the line is sloping down to the right rather than up to the right. The gradient of such a line is negative because the distance that the object is from the starting point is now decreasing – the object is going back on its path towards the start. **Displacement** means 'distance travelled in a particular direction' from a specified point. So if the object was originally travelling in a northerly direction, the negative gradient of the graph means that it is now travelling south.

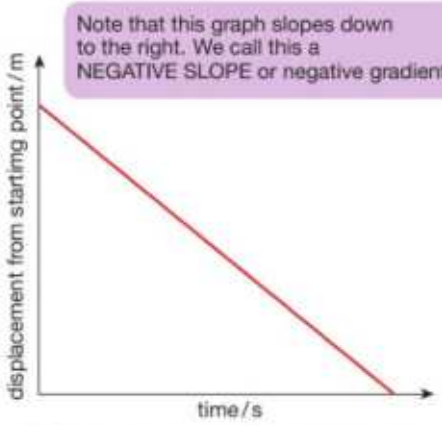
KEY POINT

A vector is a quantity that has both size and direction. Displacement is distance travelled in a particular direction. **Force** is another example of a vector that you will meet in Chapter 2. The size of a force and the direction in which it acts are both important.

Displacement is an example of a vector. Vector quantities have magnitude (size) and a specific direction.

Velocity is also a vector. Velocity is speed in a particular direction. If a car travels at 50 km/h around a bend, its speed is constant but its velocity will be changing for as long as the direction that the car is travelling in is changing.

$$\text{average velocity} = \frac{\text{increase in displacement}}{\text{time taken}}$$



▲ Figure 1.8 In this graph displacement is decreasing with time.

KEY POINT

Always show your working when answering questions. You should show your working by putting the values given in the question into the equation.

EXAMPLE 1

The global positioning system (GPS) in Figure 1.9 shows two points on a journey. The second point is 3 km north-west of the first.

a A walker takes 45 minutes to travel from the first point to the second. Calculate the average velocity of the walker.

b Explain why the average speed of the walker must be greater than this.

a Write down what you know:

increase in displacement is 3 km north-west

time taken is 45 min (45 min = 0.75 h)

$$\text{average velocity} = \frac{\text{increase in displacement}}{\text{time taken}}$$

$$= 4 \text{ km/h north-west}$$

b The walker has to follow the roads, so the distance walked is greater than the straight-line distance between A and B (the displacement). The walker's average speed (calculated using distance) must be greater than his average velocity (calculated using displacement).



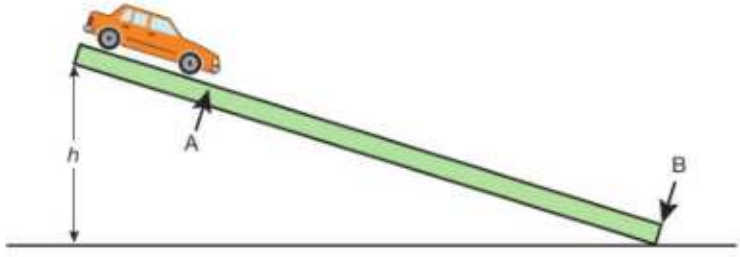
◀ Figure 1.9 The screen of a global positioning system (GPS). A GPS is an aid to navigation that uses orbiting satellites to locate its position on the Earth's surface.

ACTIVITY 1

▼ PRACTICAL: INVESTIGATE THE MOTION OF EVERYDAY OBJECTS SUCH AS TOY CARS OR TENNIS BALLS

You can use the following simple **apparatus** to investigate the motion of a toy car.

You could use this to measure the average speed, v of the car for different values of h.



▲ Figure 1.10 Investigating how a toy car rolls down a slope

Safety note: Heavy wooden runways need to be stacked and moved carefully. They are best used at low level rather than being placed on benches or tables where they may fall off. If heavy trolleys are used as 'vehicles', a 'catch box' filled with bubble wrap or similar material should be placed at the end of the runway.

You need to measure the height, *h*, of the raised end of the wooden track. The track must be securely clamped at the height under test and *h* should be measured with a metre rule making sure that the rule is **perpendicular** to the bench surface. Make sure that you always measure to the same point or mark on the raised end of the track (a fiducial mark).

To find the average speed you will use the equation:

$$\text{average speed, } v = \frac{\text{distance moved, } s}{\text{time taken, } t}$$

so you will need to measure the distance AB with a metre rule and measure the time it takes for the car to travel this distance with a stop clock. When timing with a stop clock, human **reaction** time will introduce measurement errors. To make these smaller the time to travel distance AB should, for a given value of *h*, be measured at least three times and an average value found. Always start the car from the same point, A. If one value is quite different from the others it should be treated as anomalous (the result is not accurate) and ignored or repeated.

The results should be presented in a table like the one below.

You do not need to include these equations in your table headings but you may be asked to show how you did the calculations.

Distance / m AB:					
Height, h / m	Time, *t* / s			Average time, *t* / s *t* = (*t*1 + *t*2 + *t*3) ÷ 3	Average speed, *v* / m / s *v* = AB ÷ *t*
	*t*1	*t*2	*t*3		

In a question you may be given a complete set of results or you may be required to complete the table by doing the necessary calculations. You may be asked to plot a graph (see general notes above) and then draw a conclusion. The conclusion you draw must be explained with reference to the graph, for example, if the best fit line through the plotted points is a straight line and it passes through the origin (the 0, 0 point) you can conclude that there is a **proportional** relationship between the quantities you have plotted on the graph.

Some alternative methods

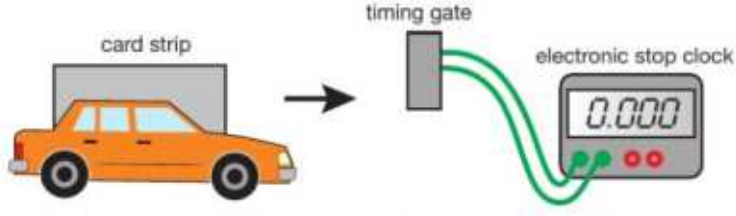
You could investigate the motion of moving objects using photographic methods either by:

- carrying out the experiment in a darkened room using a **stroboscope** to light up the object at regular known intervals (found from the **frequency** setting on the stroboscope) with the camera adjusted so that the shutter is open for the duration of the movement, or
- using a video camera and noting how far the object has travelled between each frame – the frame rate will allow you to calculate the time between each image.

In either case a clearly marked measuring scale should be visible.

Or you could use an electronically operated stop clock and electronic timing gates. This will let you measure the time that it takes for the moving object to travel over a measured distance. This has the advantage of removing timing errors produced by human reaction time.

You can also use timing gates to measure how the speed of the object changes as it moves.



▲ Figure 1.11 Using a timing gate is a more accurate method for measuring time taken to travel a distance.

In this arrangement the stop clock will time while the card strip attached to the moving car passes through the timing gate. Measuring the length of the card strip and the time it takes for the card strip to pass through the timing gate allows you to calculate the average speed of the car as it passes through the timing gate.

ACCELERATION

Figure 1.12 shows some objects whose speed is changing. The plane must accelerate to reach take-off speed. In ice hockey, the puck (small disc that the player hits) decelerates only very slowly when it slides across the ice. When the egg hits the ground it is forced to decelerate (decrease its speed) very rapidly. Rapid deceleration can have destructive results.



▲ Figure 1.12 Acceleration ...



... constant speed ...



... and deceleration

Acceleration is the rate at which objects change their velocity. It is defined as follows:

$$\text{acceleration, } a = \frac{\text{change in velocity}}{\text{time taken, } t} \text{ or } \frac{\text{final velocity, } v - \text{initial velocity, } u}{\text{time taken, } t}$$

$$a = \frac{(v - u)}{t}$$

Why u? Simply because it comes before v!

Acceleration, like velocity, is a vector because the direction in which the acceleration occurs is important as well as the size of the acceleration.

UNITS OF ACCELERATION

Velocity is measured in m/s, so increase in velocity is also measured in m/s. Acceleration, the rate of increase in velocity with time, is therefore measured in m/s/s (read as 'metres per second per second'). We normally write this as m/s^2 (read as 'metres per second **squared**'). Other units may be used – for example, cm/s^2.

HINT

It is good practice to include units in equations – this will help you to supply the answer with the correct unit.

EXAMPLE 2

A car is travelling at 20 m/s. It accelerates steadily for 5 s, after which time it is travelling at 30 m/s. Calculate its acceleration.

Write down what you know:

initial or starting velocity, $u = 20$ m/s

final velocity, $v = 30$ m/s

time taken, $t = 5$ s

$$a = \frac{(v - u)}{t}$$

$$= \frac{30\,\text{m/s} - 20\,\text{m/s}}{5\,\text{s}}$$

$$= \frac{10\,\text{m/s}}{5\,\text{s}}$$

The car is accelerating at 2 m/s^2.

DECELERATION

Deceleration means slowing down. This means that a decelerating object will have a smaller final velocity than its starting velocity. If you use the equation for finding the acceleration of an object that is slowing down, the answer will have a negative sign. A negative acceleration simply means deceleration.

EXAMPLE 3

An object hits the ground travelling at 40 m/s. It is brought to rest in 0.02 s. What is its acceleration?

Write down what you know:

initial velocity, $u = 40$ m/s

final velocity, $v = 0$ m/s

time taken, $t = 0.02$ s

$$a = \frac{(v - u)}{t}$$

$$= \frac{0\,\text{m/s} - 40\,\text{m/s}}{0.02\,\text{s}}$$

$$= \frac{-40\,\text{m/s}}{0.02\,\text{s}}$$

$$= -2000\,\text{m/s}^2$$

In Example 3, we would say that the object is decelerating at 2000 m/s^2. This is a very large deceleration. Later, in Chapter 3, we shall discuss the consequences of such a rapid deceleration!

MEASURING ACCELERATION

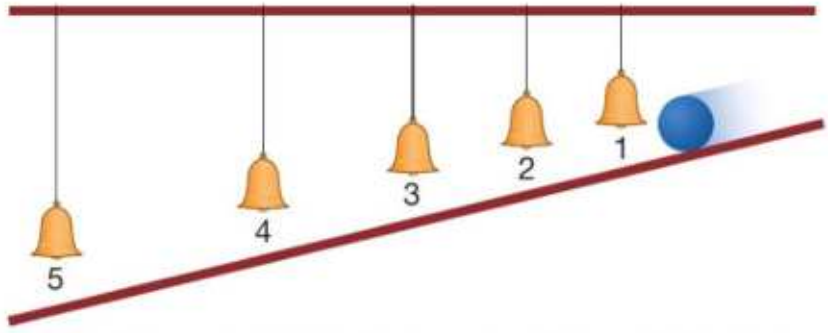
EXTENSION WORK

Galileo was an Italian scientist who was born in 1564. He developed a telescope, which he used to study the movement of the planets and stars. He also carried out many experiments on motion (movement).

EXTENSION WORK

Though Galileo did not have a clock or watch (let alone an electronic timer), he used his pulse (the sound of his heart) and a type of water clock to achieve timings that were accurate enough for his experiments.

When a ball is rolled down a slope it is clear that its speed increases as it rolls – that is, it accelerates. Galileo was interested in how and why objects, like the ball rolling down a slope, speed up, and he created an interesting experiment to learn more about acceleration. A version of his experiment is shown in Figure 1.13.



▲ Figure 1.13 Galileo's experiment. A ball rolling down a slope, hitting small bells as it rolls

Galileo wanted to discover how the distance travelled by a ball depends on the time it has been rolling. In this version of the experiment, a ball rolling down a slope strikes a series of small bells as it rolls. By adjusting the positions of the bells carefully it is possible to make the bells ring at equal intervals of time as the ball passes. Galileo noticed that the distances travelled in equal time intervals increased, showing that the ball was travelling faster as time passed. Galileo did not have an accurate way of measuring time (there were no digital stopwatches in seventeenth-century Italy!) but it was possible to judge equal time intervals accurately simply by listening.

Galileo also noticed that the distance travelled by the ball increased in a predictable way. He showed that the rate of increase of speed was steady or uniform. We call this uniform acceleration. Most acceleration is non-uniform – that is, it changes from instant to instant – but we shall only deal with uniformly accelerated objects in this chapter.

VELOCITY–TIME GRAPHS

The table below shows the distances between the bells in an experiment such as Galileo's.

Bell	1	2	3	4	5
Time / s	0.5	1.0	1.5	2.0	2.5
Distance of bell from start / cm	3	12	27	48	75

We can calculate the average speed of the ball between each bell by working out the distance travelled between each bell, and the time it took to travel this distance. For the first bell:

$$\text{velocity, } v = \frac{\text{distance moved, } s}{\text{time taken, } t}$$

$$= \frac{3\text{ cm}}{0.5\text{ s}} = 6\text{ cm/s}$$

This is the average velocity over the 0.5 second time interval, so if we plot it on a graph we should plot it in the middle of the interval, at 0.25 seconds.

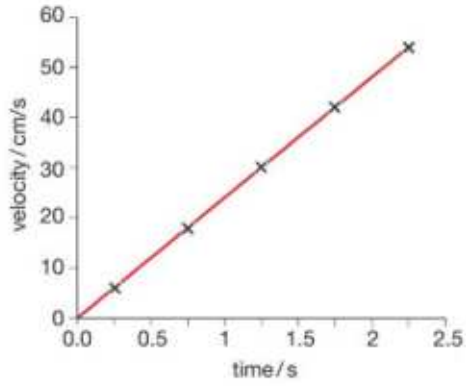
Repeating the above calculation for all the results gives us the following table of results. We can use these results to draw a graph showing how the velocity of the ball is changing with time. The graph, shown in Figure 1.14, is called a velocity–time graph.

Time / s	0.25	0.75	1.25	1.75	2.25
Velocity / cm/s	6	18	30	42	54

KEY POINT

The equations of motion we have learned work for uniform or constant acceleration only – therefore for objects with velocity–time graphs that are straight lines.

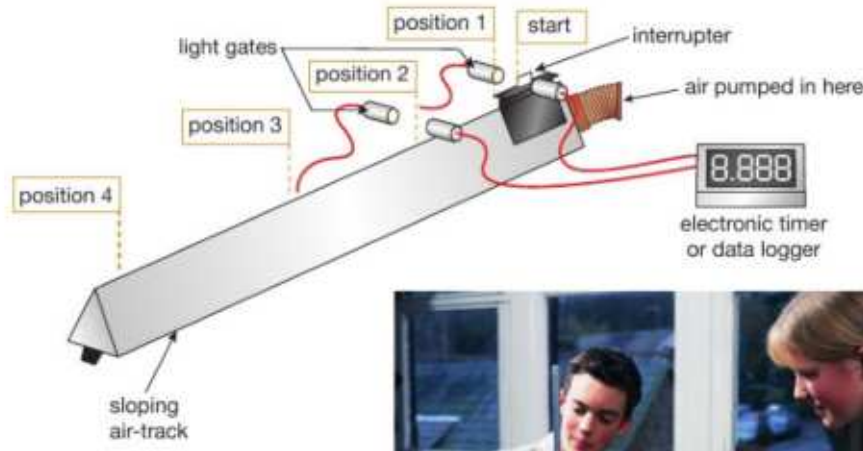
The graph in Figure 1.14 is a straight line. This tells us that the velocity of the rolling ball is increasing by equal amounts in equal time periods. We say that the acceleration is uniform in this case.



▲ Figure 1.14 Velocity–time graph for an experiment in which a ball is rolled down a slope. (Note that as we are plotting average velocity, the points are plotted in the middle of each successive 0.5 s time interval.)

A MODERN VERSION OF GALILEO'S EXPERIMENT

Safety note: A cylinder vacuum cleaner (or similar) used with the air-track should be placed on the floor as it may fall off a bench or stool. Also, beware of any trailing leads.



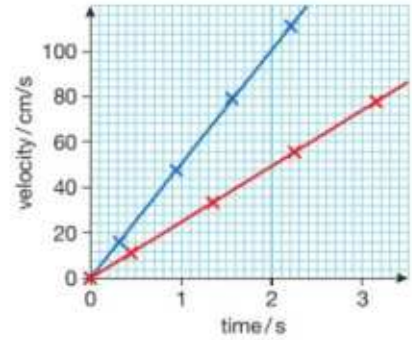


▲ Figure 1.15 Measuring acceleration

Today we can use data loggers to make accurate direct measurements that are collected and analysed by a computer. A spreadsheet program can be used to produce a velocity–time graph. Figure 1.15 shows a glider on a slightly sloping air-track. The air-track reduces **friction** because the glider rides on a cushion of air that is pushed continuously through holes along the air-track. As the glider accelerates down the sloping track the card stuck on it breaks a light beam, and the time that the glider takes to pass is measured electronically. If the length of the card is measured, and this is entered into the spreadsheet, the velocity of the glider can be calculated by the spreadsheet program using $v = \frac{s}{t}$.

Figure 1.16 shows velocity–time graphs for two experiments done using the air-track apparatus. In each experiment the track was given a different slope. The steeper the slope of the air-track the greater the glider's acceleration. This is clear from the graphs: the greater the acceleration the steeper the gradient of the graph.

The gradient of a velocity–time graph gives the acceleration.



Air-track at 1.5°		Air-track at 3.0°	
Time/s	Av Vel. /cm/s	Time/s	Av Vel. /cm/s
0.00	0.0	0.00	0.0
0.45	11.1	0.32	15.9
1.35	33.3	0.95	47.6
2.25	55.6	1.56	79.4
3.15	77.8	2.21	111.1

▲ Figure 1.16 Results of two air-track experiments. (Note, once again, that because we are plotting average velocity in the velocity–time graphs, the points are plotted in the middle of each successive time interval – see page 497)

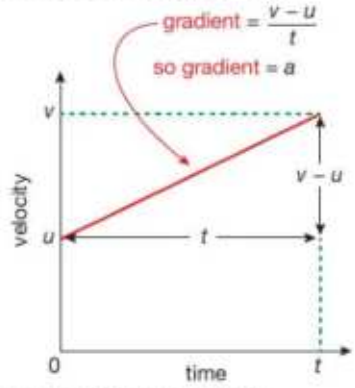
MORE ABOUT VELOCITY–TIME GRAPHS

GRADIENT

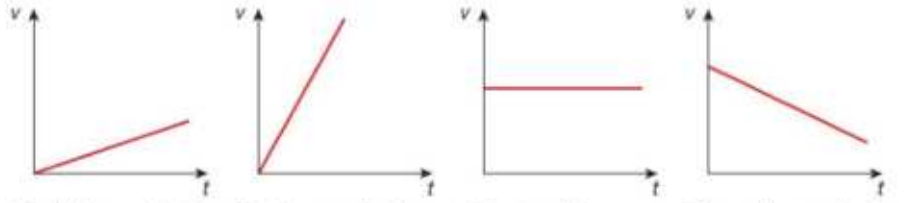
The results of the air-track experiments in Figure 1.16 show that the slope of the velocity–time graph depends on the acceleration of the glider. The slope or gradient of a velocity–time graph is found by dividing the increase in the velocity by the time taken for the increase, as shown in Figure 1.17. In this example an object is travelling at u m/s at the beginning and accelerates uniformly (at a constant rate) for t s. Its final velocity is v m/s. Increase in velocity divided by time is, you will recall, the definition of acceleration (see page 495), so we can measure the acceleration of an object by finding the slope of its velocity–time graph. The meaning of the slope or gradient of a velocity–time graph is summarised in Figure 1.17.

HINT

1 When finding the gradient of a graph, draw a big triangle.
2 Choose a convenient number of units for the length of the base of the triangle to make the division easier.



▲ Figure 1.17 Finding the gradient of a velocity–time graph



a shallow gradient – low acceleration

b steep gradient – high acceleration

c horizontal (zero gradient) – no acceleration

d negative gradient – negative acceleration (deceleration)

▲ Figure 1.18 The gradient of a velocity–time graph gives you information about the motion of an object at a glance.

AREA UNDER A VELOCITY–TIME GRAPH GIVES DISTANCE TRAVELLED

Figure 1.19a shows a velocity–time graph for an object that travels with a constant velocity of 5 m/s for 10 s. A simple calculation shows that in this time the object has travelled 50 m. This is equal to the shaded (coloured) area under the graph. Figure 1.19b shows a velocity–time graph for an object that has accelerated at a constant rate. Its average velocity during this time is given by:

$$\text{average velocity} = \frac{\text{initial velocity} + \text{final velocity}}{2} \text{ or } \frac{u+v}{2}$$

In this example the average velocity is, therefore:

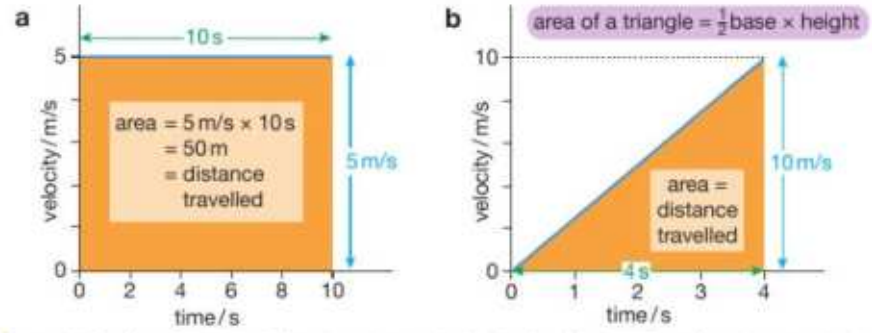
$$\text{average velocity} = \frac{0\,\text{m/s} + 10\,\text{m/s}}{2}$$

which works out to be 5 m/s. If the object travels, on average, 5 metres in each second it will have travelled 20 metres in 4 seconds. Notice that this, too, is equal to the shaded area under the graph (given by the area equation for a triangle: area = $\frac{1}{2}$ base × height).

HINT

Find the distance travelled for more complicated velocity–time graphs by dividing the area beneath the graph line into rectangles and triangles. Take care that units on the velocity and time axes use the same units for time, for example, m/s and s, or km/h and h.

The area under a velocity–time graph is equal to the distance travelled by (displacement of) the object in a particular time interval.



▲ Figure 1.19 a An object travelling at constant velocity; b An object accelerating at a constant rate

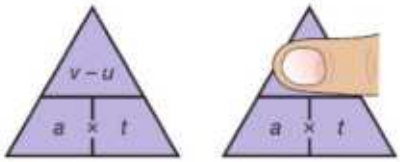
EQUATIONS OF UNIFORMLY ACCELERATED MOTION

You must remember the equation:

$$a = \frac{v - u}{t}$$

and be able to use it to calculate the acceleration of an object.

You may need to rearrange the equation to make another term the subject.



▲ Figure 1.20 Cover $v - u$ to find $v - u = a \times t$

EXAMPLE 4

A stone accelerates from rest uniformly at 10 m/s² when it is dropped down a deep well. It hits the water at the bottom of the well after 5 s. Calculate how fast it is travelling when it hits the water.

You will need to make v the subject of this equation:

$$a = \frac{v - u}{t}$$

You can use the triangle method to show that $v - u = a \times t$

then add u to both sides of the equation to give:

$$v = u + at$$

(In words this tells you that the final velocity is the initial velocity plus the increase in velocity after accelerating for t seconds.)

State the things you have been told:

initial velocity, $u = 0$ m/s (It was stationary (standing still) at the start.)

acceleration, $a = 10$ m/s²

time, t, of the acceleration = 5 s

Substitute these into the equation: $v = 0$ m/s + (10 m/s² × 5 s)

Then calculate the result.

The stone hit the water travelling at 50 m/s (downwards).

You will also be required to use the following equation of uniformly accelerated motion:

(final speed)², v^2 = (initial speed)², u^2 + (2 × acceleration, a × distance moved, s)

$$v^2 = u^2 + 2as$$

EXAMPLE 5

A cylinder containing a vaccine is dropped from a helicopter hovering at a height of 200 m above the ground. The acceleration due to **gravity** is 10 m/s^2. Calculate the speed at which the cylinder will hit the ground.

You are given the acceleration, $a = 10$ m/s^2, and the distance, $s = 200$ m, through which the cylinder moves. The initial velocity, u, is not stated, but you assume it is 0 m/s as the helicopter is hovering (staying in one place in the air). Substitute these values in the given equation:

$$v^2 = u^2 + 2as$$

$$= 0 \text{ m/s}^2 + (2 \times 10 \text{ m/s}^2 \times 200 \text{ m})$$

$$= 4000 \text{ m}^2/\text{s}^2$$

therefore $v = \sqrt{(4000 \text{ m}^2/\text{s}^2)}$

$$= 63.25 \text{ m/s}$$

LOOKING AHEAD

The equations you have seen in this chapter are called the equations of uniformly accelerated motion. This means that they will give you correct answers when solving any problems that have objects moving with constant acceleration. In your exam you will only see problems where this is the case or very nearly so. Examples in which objects accelerate or decelerate (slow down) at a constant rate often have a constant acceleration due to the Earth's gravity (which we take as about 10 m/s^2).

In real life, problems may not be quite so simple! Objects only fall with constant acceleration if we ignore air resistance and the distance that they fall is quite small.

These equations of uniformly accelerated motion are often called the 'suvat' equations, because they show how the terms s (distance moved), u (velocity at the start), v (velocity at the finish), a (acceleration) and t (time) are related.

CHAPTER QUESTIONS

More questions on speed and acceleration can be found at the end of Unit 1 on page 526.

SKILLS PROBLEM SOLVING

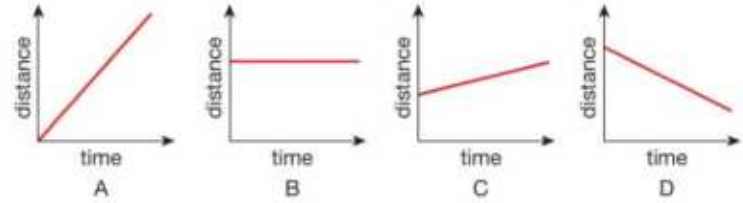
1 A sprinter runs 100 metres in 12.5 seconds. Calculate the speed in m/s.

2 A jet can travel at 350 m/s. Calculate how far it will travel at this speed in:
   a 30 seconds
   b 5 minutes
   c half an hour.

3 A snail crawls at a speed of 0.0004 m/s. How long will it take to climb a garden stick 1.6 m high?

SKILLS ANALYSIS

4 Look at the following distance–time graphs of moving objects.



Identify in which graph the object is:

a moving backwards

b moving slowly

c moving quickly

d not moving at all.

SKILLS INTERPRETATION

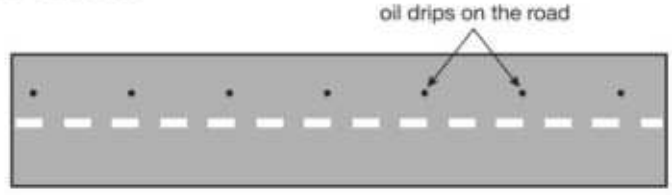
5 Sketch a distance–time graph to show the motion of a person walking quickly, stopping for a moment, then continuing to walk slowly in the same direction.

6 Plot a distance–time graph using the data in the following table. Draw a line of best fit and use your graph to find the speed of the object concerned.

Distance / m	0.00	1.60	3.25	4.80	6.35	8.00	9.60
Time / s	0.00	0.05	0.10	0.15	0.20	0.25	0.30

SKILLS PROBLEM SOLVING

7 The diagram below shows a trail of oil drips made by a car as it travels along a road. The oil is dripping from the car at a steady rate of one drip every 2.5 seconds.



a Describe the way the car is moving.

b The distance between the first and the seventh drip is 135 metres. Determine the average speed of the car.

8 A car is travelling at 20 m/s. It accelerates uniformly at 3 m/s^2 for 5 s.

a Sketch a velocity–time graph for the car during the period that it is accelerating. Include numerical detail on the axes of your graph.

b Calculate the distance the car travels while it is accelerating.

SKILLS INTERPRETATION

9 Explain the difference between the following terms:

a average speed and instantaneous speed

b speed and velocity.

SKILLS PROBLEM SOLVING

10 A sports car accelerates uniformly from rest to 24 m/s in 6 s. Calculate the acceleration of the car.

SKILLS INTERPRETATION

11 Sketch velocity–time graphs for an object:

a moving with a constant velocity of 6 m/s

b accelerating uniformly from rest at 2 m/s^2 for 10 s

c decelerating to rest at 4 m/s^2 for 5 s.

Include numbers and units on the velocity and time axes in each case.

SKILLS PROBLEM SOLVING

12 A plane starting from rest accelerates at 3 m/s² for 25 s. Calculate the increase in velocity after:

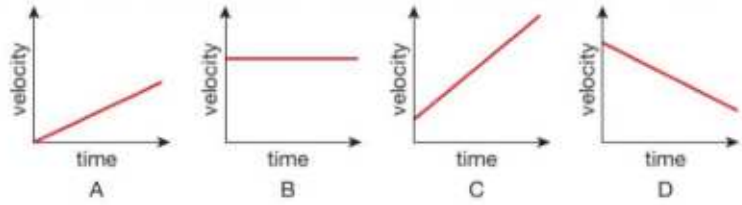
a 1 s

b 5 s

c 25 s.

SKILLS ANALYSIS

13 Look at the following sketches of velocity–time graphs of moving objects.



In which graph is the object:

a not accelerating

b accelerating from rest

c decelerating

d accelerating at the greatest rate?

SKILLS INTERPRETATION

14 Sketch a velocity–time graph to show how the velocity of a car travelling along a straight road changes if it accelerates uniformly from rest for 5 s, travels at a constant velocity for 10 s, then brakes hard to come to rest in 2 s.

15 a Plot a velocity–time graph using the data in the following table:

Velocity / m/s	0.0	2.5	5.0	7.5	10.0	10.0	10.0	10.0	10.0	10.0
Time / s	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0

Draw a line of best fit and use your graph to find:

b the acceleration during the first 4 s

c the distance travelled in:

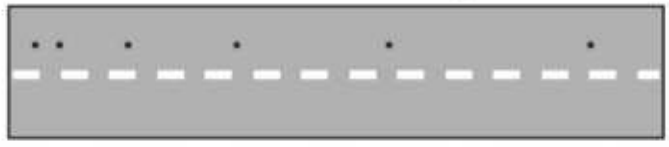
i the first 4 s of the motion shown

ii the last 5 s of the motion shown

d the average speed during the 9 seconds of motion shown.

SKILLS CRITICAL THINKING

16 The dripping car from Question 7 is still on the road! It is still dripping oil but now at a rate of one drop per second. The trail of drips is shown on the diagram below as the car travels from left to right.



Describe the motion (the way the car is moving) using the information in this diagram.

SKILLS PROBLEM SOLVING

17 This question uses the equation $v^2 = u^2 + 2as$.

a Explain what each of the terms in this equation represents.

b A ball is thrown vertically upwards at 25 m/s. Gravity causes the ball to decelerate at 10 m/s². Calculate the maximum height the ball will reach.

2 FORCES AND SHAPE

Forces are acting on us, and on objects all around us, all the time. In this chapter you will learn about different kinds of forces, how they may change the speed and direction of objects and how they can affect the shape of objects.



▲ Figure 2.1 Forces include pulling, falling due to gravity and squashing

LEARNING OBJECTIVES

- Describe the effects of forces between bodies such as changes in speed, shape or direction
- Identify different types of force such as gravitational or electrostatic
- Understand how vector quantities differ from scalar quantities
- Understand that force is a vector quantity
- Calculate the resultant force of forces that act along a line
- Know that friction is a force that opposes motion
- Practical: investigate how extension varies with applied force for helical springs, metal wires and rubber bands
- Know that the initial linear region of a force–extension graph is associated with Hooke's law
- Describe elastic behaviour as the ability of a material to recover its original shape after the forces causing deformation have been removed

Forces are simply pushes and pulls of one thing on another. Sometimes we can see their effects quite clearly. In Figure 2.1, the tug is pulling the tanker; the bungee jumper is being pulled to Earth by the force of gravity, and then (hopefully before meeting the ground) being pulled back up by the stretched elastic rope; the force applied by the crusher permanently changes the shape of the cars. In this chapter we will discuss different types of forces and look at their effects on the way that objects move.

ALL SORTS OF FORCES

If you are to study forces, first you need to notice them! As we have already said, sometimes they are easy to see and their effect is obvious. Look at Figure 2.2 and try to identify any forces that you think are involved.

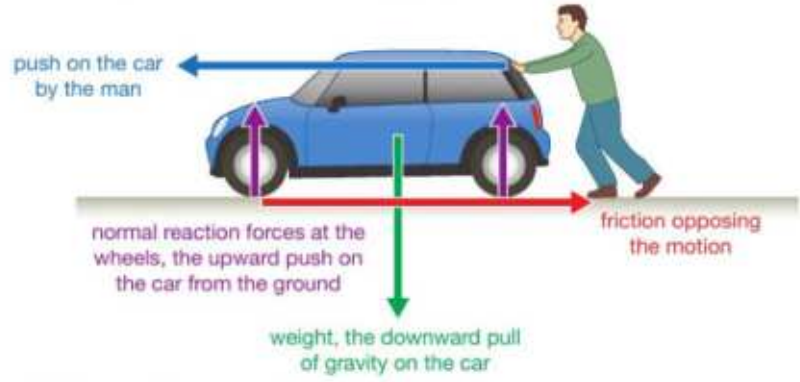


▲ Figure 2.2 What forces do you think are working here?

You will immediately see that the man is applying a force to the car – he is pushing it. But there are quite a few more forces in the picture. To make the task a little easier we will limit our search to just those forces acting on the car. We will also ignore forces that are very small and therefore have little effect.

The man is clearly struggling to make the car move. This is because there is a force acting on the car trying to stop it moving. This is the force of friction between the moving parts in the car engine, gears, wheel axles and so on. This unhelpful force opposes the motion that the man is trying to achieve. However, when the car engine is doing the work to make the car go, the friction between the tyres and the road surface is vital. On an icy road even powerful cars may not move forward because there is not enough friction between the tyres and the ice.

Another force that acts on the car is the pull of the Earth. We call this a gravitational force or simply **weight**. If the car were to be pushed over the edge of a cliff, the effect of the gravitational force would be very clear as the car fell towards the sea. This leads us to realise that yet another force is acting on the car in Figure 2.2 – the road must be stopping the car from being pulled into the Earth. This force, which acts in an upward direction (going up) on the car, is called the reaction force. (A more complete name is **normal** reaction force. Here the word 'normal' means acting at 90° to the road surface.) All four forces that act on the car are shown in Figure 2.3.



▲ Figure 2.3 There are four types of force at work.

You will have realised by now that it is not just the size of the force that is important – the direction in which the force is acting is important, too.

Force is another example of a vector.

KEY POINT

Like displacement, velocity and acceleration, force is a *vector quantity* because both its size and direction matter. Some quantities, such as temperature, have no direction connected with them. They are known as *scalar quantities*.

UNITS OF FORCE

The unit used to measure force is the newton (N), named after Sir Isaac Newton. Newton's study of forces is vital to our understanding of them today.

A force of one newton will make a **mass** of one kilogram accelerate at one metre per second squared.

This is explained more fully later (see Chapter 3). To give you an idea of the size of the newton, the force of gravity on a kilogram bag of sugar (its weight) is about 10 N; an average-sized apple weighs 1 N.

a



b



▲ Figure 2.4 More forces!

SOME OTHER EXAMPLES OF FORCES

It is not always easy to spot forces acting on objects. The compass needle in Figure 2.4a, which is a magnet, is affected by the magnetic force between it and the other magnet. Magnetic forces are used to make electric motors **rotate**, to hold fridge doors shut, and in many other situations.

If you comb your hair, you sometimes find that some of your hair sticks to the comb as shown in Figure 2.4b. This happens because of an electrostatic force between your hair and the comb. You can see a similar effect using a Van de Graaff **generator**.

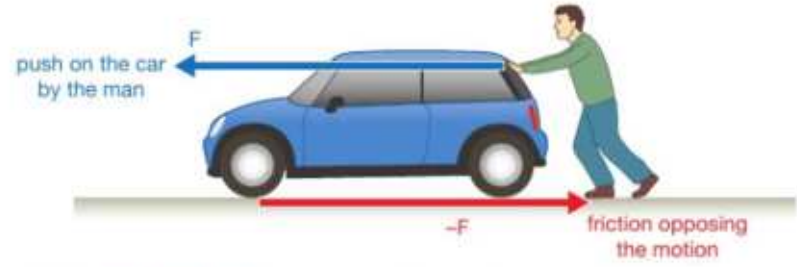
A parachute causes the parachutist to descend more slowly because an upward force acts on the parachute called air resistance or drag. Air resistance is like friction – it tries to oppose movement of objects through the air. Designers of cars, high-speed trains and other fast-moving objects try to reduce the effects of this force. Objects moving through liquids also experience a drag force – fast-moving animals that live in water have streamlined (smooth and efficient) shapes to reduce this force.

Hot air balloons are carried upwards in spite of the pull of gravity on them because of a force called **upthrust**. This is the upward push of the surrounding air on the balloon. An upthrust force also acts on objects in liquids.

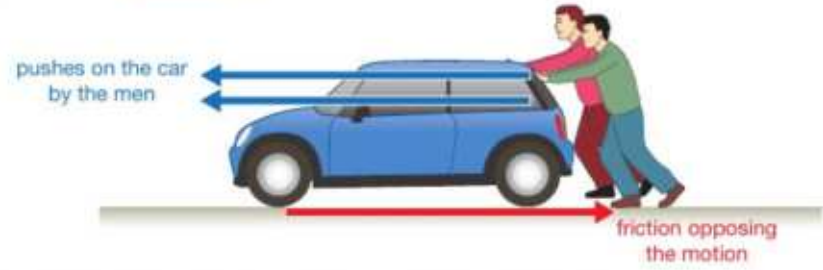
More types of force, such as electric and **nuclear** forces, are mentioned in other chapters of this book. The rest of this chapter will look at the effects of forces.

MORE THAN ONE FORCE

As we saw earlier, in most situations there will be more than just one force acting on an object. Look at the man trying to push the car, shown in Figure 2.5. The two forces act along the same line, but in opposite directions. This means that one is negative (because it acts in the opposite direction to the other) and, if they are equal in size, they add up to zero and the car will not move.



▲ Figure 2.5 The **resultant force** is zero because the two forces are balanced.



▲ Figure 2.6 The total pushing force is the **sum** of the two individual forces.

If the man gets someone to help him push the car, the forward force is bigger. Both of the forces pushing the car are acting in the same direction, so you can find the total forward force by adding the two forces together. If both people are pushing with a force of 300 N, then:

$$\text{total forward force} = 300\ \text{N} + 300\ \text{N}$$
$$= 600\ \text{N}$$

This means we can just add all the forces together to find the resultant force. As force is a vector quantity, we also need to think about the directions in which the forces are acting, and we do this by deciding which direction is the positive (+) direction. In this case, we can think of the force from the people as positive and the force from friction as negative. The + and – signs just show that the forces are acting in opposite directions.

So, if the force from friction is 300 N:

$$\textbf{unbalanced force} = 300\ \text{N} + 300\ \text{N} - 300\ \text{N}$$
$$= 300\ \text{N}$$

BALANCED AND UNBALANCED FORCES



▲ Figure 2.7 Balanced forces and unbalanced forces

Figure 2.7 shows two situations in which forces are acting on an object. In the tug of war contest the two teams are pulling on the rope in opposite directions. For much of the time the rope doesn't move because the two forces are balanced. This means that the forces are the same size but act in opposite directions along the line of the rope. There is no unbalanced force in one direction or the other. When the forces acting on something are balanced, the object does not change the way it is moving. In this case if the rope is stationary, it remains stationary. Eventually, one of the teams will become tired and its pull will be smaller than that of the other team. When the forces acting on the rope are unbalanced the rope will start to move in the direction of the greater force. There will be an unbalanced force in that direction. Unbalanced forces acting on an object cause it to change the way it is moving. The rope was stationary and the unbalanced forces acting on it caused it to accelerate.

The car in Figure 2.7 is designed to have an enormous acceleration from rest. As soon as it starts to move the forces that oppose motion – friction and drag – must be overcome. The **thrust** of the engine is, to start with, much greater than the friction and drag forces. This means that the forces acting on the car in the horizontal direction are unbalanced and the result is a change in the way that the car is moving – it accelerates! Once the friction forces balance the thrust the car no longer accelerates – it moves at a steady speed.

FRICTION

Friction is the force that causes moving objects to slow down and finally stop. The **kinetic energy** of the moving object is transferred to heat as work is done by the friction force. For the ice skater in Figure 2.8 the force of friction is very small so she is able to glide for long distances without having to do any work. It is also the force that allows a car's wheels to grip the road and make it accelerate – very quickly in the case of the racing cars in Figure 2.8.

Scientists have worked hard for many years to develop some materials that reduce friction and others that increase friction. Reducing friction means that machines work more efficiently (wasting less energy) and do not wear out so quickly. Increasing friction can help to make tyres that grip the road better and to make more effective brakes.

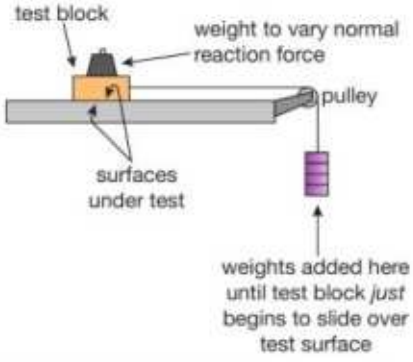




▲ Figure 2.8 The ice skater can glide because friction is low. The cars need friction to grip the road.

Friction occurs when solid objects rub against other solid objects and also when objects move through fluids (liquids and gases). Sprint cyclists and Olympic swimmers now wear special materials to reduce the effects of fluid friction so they can achieve faster times in their races. Sometimes fluid friction is very desirable – for example, when someone uses a parachute after jumping from a plane!

INVESTIGATING FRICTION



▲ Figure 2.9 This apparatus can be used to investigate friction.

Safety note: A 'catch box' filled with bubble wrap (or similar) under the suspended masses keeps hands and feet out of the 'drop zone'.

The simple apparatus shown in Figure 2.9 can be used to discover some basic facts about friction. The weight force on the line running over the pulley pulls the block horizontally along the track and friction acts on the block to oppose this force. The weight is increased until the block just starts to move; this happens when the pull of the weight force just overcomes the friction force. The friction force between the block and the track has maximum value.

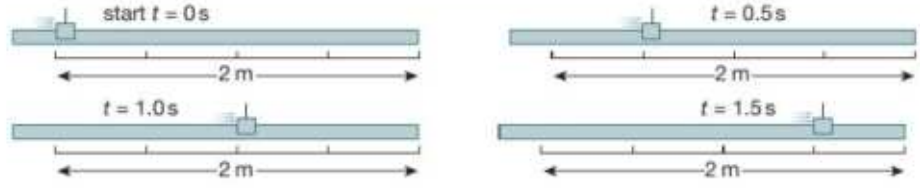
The apparatus can be used to test different factors that may affect the size of the friction force, such as the surfaces in contact – the bottom of the block and the surface of the track. If the track surface is replaced with a rough surface, like a sheet of sandpaper, the force required to overcome friction will be greater.

It is important to remember friction when you are investigating forces and motion. Friction affects almost every form of motion on Earth. However it is possible to do experiments in the science laboratory in which the friction force on a moving object is reduced to a very low value. Such an object can be set in motion with a small push and it will continue to move at a constant speed even when the force is no longer acting on it. An experiment like this is shown in Figure 2.10.

You may also have seen scientists working in space demonstrating that objects keep moving in a straight line at constant speed, once set in motion. They do this in space because the objects are **weightless** and the force of air resistance acting on them is very small.

EXTENSION WORK

Objects in orbit, such as spacecraft, are described as 'weightless' because they do not appear to have weight. However the Earth's gravity is still acting on them, and on the spacecraft. You can think of a spacecraft in orbit as 'falling around the Earth'. As the objects inside the spacecraft are also falling around the Earth at the same rate, they do not seem to fall inside the spacecraft.



▲ Figure 2.10 A linear (straight line) air-track reduces friction dramatically. The glider moves equal distances in equal time intervals. Its velocity is constant.





▲ Figure 2.11 Forces can cause changes in shape.

CHANGING SHAPES

We have seen that forces can make things start to move, accelerate or decelerate. The examples in Figure 2.11 show another effect that forces can have – they can change the shape of an object.

Sometimes the change of shape is temporary, as in the suspension spring in the mountain bike (Figure 2.11a). Sometimes the shape of the object is permanently changed, like a crushed can or a car that has collided with another object. A temporary change of shape may provide a useful way of absorbing and storing energy, as in the spring in a clock (Figure 2.11b). A permanent change may mean the failure of a structure like a bridge to support a load. Next we will look at temporary changes in the lengths of springs and elastic bands.

TEMPORARY CHANGES OF SHAPE

If you apply a force to an elastic band, its shape changes – the band stretches and gets longer. All materials will stretch a little when you put them under tension (that is, pull them) or shorten when you compress or squash them. You can stretch a rubber band quite easily, but a huge force is needed to cause a noticeable extension in a piece of steel of the same length.

Some materials, like glass, do not change shape easily and are brittle, breaking rather than stretching noticeably. Elastic materials do not break easily and tend to return to their original shape when the forces acting on them are removed, like the spring in Figure 2.11b. Other materials, like putty and modelling clay, are not elastic but plastic, and they change shape when even quite small forces are applied to them.

We will look at elastic materials, like rubber, metal wires and metals formed into springs, in the next part of this chapter.

SPRINGS AND WIRES

Springs are coiled lengths of certain types of metal, which can be stretched or **compressed** by applying a force to them. They are used in many different situations. Sometimes they are used to absorb raised bumps in the road as suspension springs in a car or bicycle. In beds and chairs they are used to make sleeping and sitting more comfortable. They are also used in door locks to hold them closed and to make doors close automatically.

To choose the right spring for a particular use, we must understand some important features of springs. A simple experiment with springs shows us that:

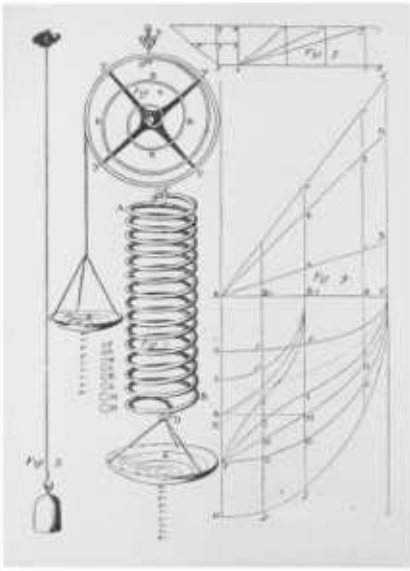
> *Springs change length when a force acts on them and they return to their original length when the force is removed.*

This is true provided you do not stretch them too much. If springs are stretched beyond a certain point they do not spring back to their original length.

HOOKE'S LAW

Robert Hooke discovered another important property of springs. He used simple apparatus like that shown in Figure 2.12.

Hooke measured the increase in length (extension) produced by different load forces on springs. The graph he obtained by plotting force against extension was a straight line passing through the origin. This shows that the extension of the spring is proportional to the force. This relationship is known as Hooke's law.



▲ Figure 2.12 Robert Hooke (1635–1703) was a contemporary of Sir Isaac Newton. This is a drawing of the apparatus Hooke used in his experimental work on the extension of a spring.

Safety note: Wear eye protection if heavy loads are being used and clamp stands securely to a bench or table. Keep hands and feet away from beneath the load. Do not use excessively large loads.

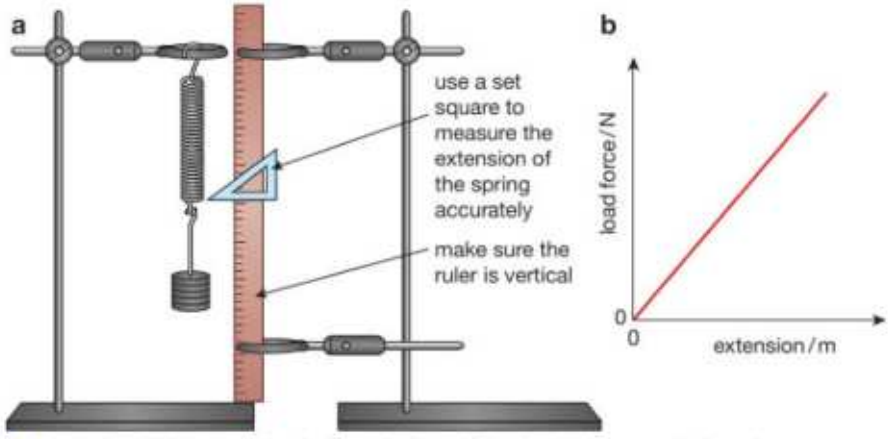
ACTIVITY 2

▼ PRACTICAL: INVESTIGATE HOW THE EXTENSION OF A SPRING CHANGES WITH LOAD

Figure 2.13a shows apparatus that may be used to investigate the relationship between the force applied to a spring and its extension.

The length of the unstretched spring is measured with a half-metre rule then the spring is loaded with different weights. The extension for each load is measured against a scale using a set square to improve measurement accuracy.

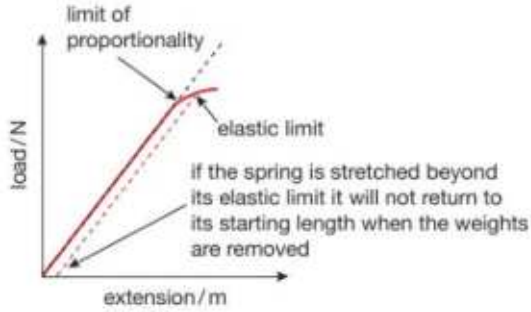
A table of results is recorded and a graph of load force against extension plotted as shown in Figure 2.13b. The extension measurements can be checked by unloading the weights one at a time and remeasuring the extension for each load.



▲ Figure 2.13 **a** Apparatus for the investigation **b** Graph showing expected result

Here the result is a straight line graph passing through the origin of the axes. The spring obeys Hooke's law.

Hooke's law only applies if you do not stretch a spring too far. Figure 2.14 shows what happens if you stretch a spring too far. You can see that the line starts to curve at a point called the limit of proportionality. This is the point where the spring stops obeying Hooke's law and starts to stretch more for each increase in the load force. If the load is increased more, a point called the elastic limit is reached. Once you have stretched a spring beyond the elastic limit it will not return to its original length as you take the weights off the spring.



▲ Figure 2.14 Graph of load v extension showing spring going beyond elastic limit

Hooke's law also applies to wires. If you stretch a wire, you will find that the extension is proportional to the load up to a certain load then it may behave as the spring shown in Figure 2.14. Wires made of different metals will behave in different ways – some will obey Hooke's law until the wire breaks; other types of metal will stretch elastically and then plastically before breaking.

ELASTIC BANDS



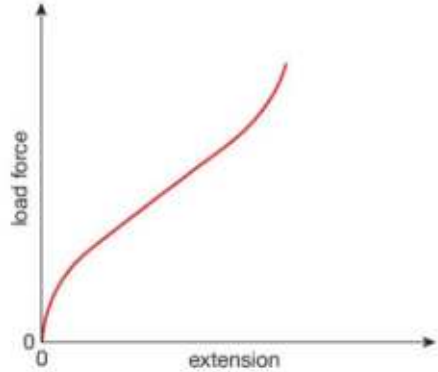
▲ Figure 2.15 Stretching an elastic band

Safety note: Wear eye protection because if the elastic band breaks it can fly back with enough energy to cause serious eye damage.

REMINDER

A wire that stretches elastically will return to its original length once the stretching force is removed. A wire that stretches plastically will not return to its original length once the stretching force is removed and may show signs of narrowing (necking).

Elastic bands are usually made of rubber. You can use the same apparatus shown in Figure 2.13a to investigate how an elastic band stretches under load. If you stretch an elastic band with increasing load forces, you get a graph like that shown in Figure 2.16. The graph is not a straight line, showing that elastic bands do not obey Hooke's law. You may also find that the extension produced by a given load force is different when you are increasing the load force to when you decrease the load force.



▲ Figure 2.16 Rubber bands do not obey Hooke's law – the extension is not directly proportional to the force causing it.

CHAPTER QUESTIONS

More questions on forces can be found at the end of Unit 1 on page 526.

SKILLS CRITICAL THINKING

1 Name the force that:
- a causes objects to fall towards the Earth
- b makes a ball rolled across level ground eventually stop
- c stops a car sinking into the road surface.

2 Name two types of force that oppose motion.

SKILLS PROBLEM SOLVING

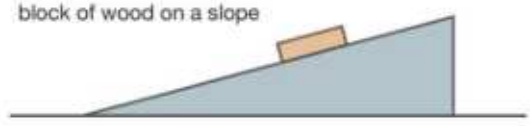
3 The drawing shows two tug-of-war teams. Each person in the red team is pulling with a force of 250 N. Each person in the blue team is pulling with a force of 200 N.



- a What is the total force exerted by the blue team?
- b What is the total force exerted by the red team?
- c What is the resultant (unbalanced) force on the rope?
- d Which team will win?

SKILLS INTERPRETATION

4 The diagram below shows a block of wood on a sloping surface. Copy the diagram and label all the forces that act on the block of wood.



5 A car is travelling along a level road at constant velocity (that is, its speed and direction are not changing). Draw a labelled diagram to show the forces that act on the car.

SKILLS CRITICAL THINKING

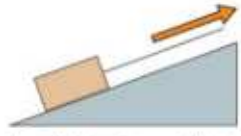
6 Describe two things that it would be impossible to do without friction.

SKILLS INTERPRETATION

7 Copy the diagrams below and label the direction in which friction is acting on the objects.

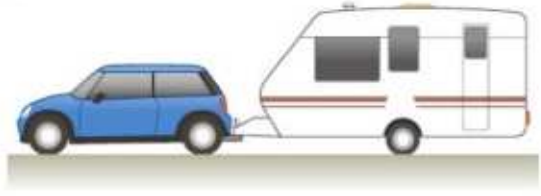


a a book on a sloping surface



b a block of wood being pulled up a slope

8 The drawing below shows a car pulling a caravan. They are travelling at constant velocity.



- a Copy the drawing. Label the forces that are acting on the caravan with arrows showing the direction that they act in.
- b Label the forces that act on the car.

SKILLS PROBLEM SOLVING

9 The information in the following table was obtained from an experiment with a spring of original (unstretched) length 5 cm.

Load force on spring / newtons	Length of spring / cm	Extension of spring / cm
0	5.0	
2	5.8	
4	6.5	
6	7.4	
8	8.3	
10	9.7	
12	12.9	

a Copy and complete the table by calculating the extensions produced by each load.

SKILLS INTERPRETATION

b Use your table to plot a graph of force (*y*-axis) against extension (*x*-axis).

c Mark on your graph the part that shows Hooke's law.

SKILLS REASONING

d Sketch the shape of the graph you would expect if you carried out the same experiment using an elastic band instead of a spring.

3 FORCES AND MOVEMENT

The way an object moves depends upon its mass and the unbalanced force acting upon it. In this chapter you will find out how forces affect the way an object will move, particularly in the context of car safety.

a 

b 

▲ Figure 3.1 **a** This aircraft has only a short distance to travel before taking off and **b** a very short distance to land back on the aircraft carrier.

LEARNING OBJECTIVES

- Know and use the relationship between unbalanced force, mass and acceleration:

  force = mass × acceleration

  $F = m \times a$
- Know and use the relationship between weight, mass and gravitational field strength:

  weight = mass × gravitational field strength

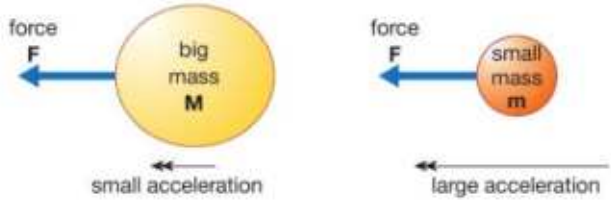
  $W = m \times g$
- Know that the stopping distance of a vehicle is made up of the sum of the thinking distance and the braking distance
- Describe the factors affecting vehicle stopping distance, including speed, mass, road condition and reaction time
- Describe the forces acting on falling objects (and explain why falling objects reach a terminal velocity)

The aircraft in Figure 3.1 must accelerate to a very high speed in a very short time when taking off and decelerate quickly when landing back on the aircraft carrier. The unbalanced force on the plane causes the acceleration. The forces that act horizontally on the aircraft are the friction force between the wheels and the flight deck (where planes land on a ship), and air resistance, when the aircraft starts to move. At the start, the forward thrust of the aircraft engines is much greater than air resistance and friction, so there is a large unbalanced force to cause the acceleration. When the aircraft lands on the flight deck it must decelerate to stop in a short distance. Parachutes and drag wires are used to provide a large unbalanced force acting in the opposite direction to the aircraft's movement. An unbalanced force is sometimes referred to as a resultant force. In this chapter we look at how acceleration is related to the force acting on an object.

FORCE, MASS AND ACCELERATION

An object will not change its velocity (accelerate) unless there is an unbalanced force acting on it. For example, a car travelling along a motorway at a constant speed is being pushed along by a force from its engine, but this force is needed to balance the forces of friction and air resistance acting on the car. At a constant speed, the unbalanced force on the car is zero.

If there are unbalanced forces acting on an object, the object may accelerate or decelerate depending on the direction of the unbalanced force. The acceleration depends on the size of the unbalanced force and the mass of the object.



a When the same force is applied to objects with different mass, the smaller mass will experience a greater acceleration.



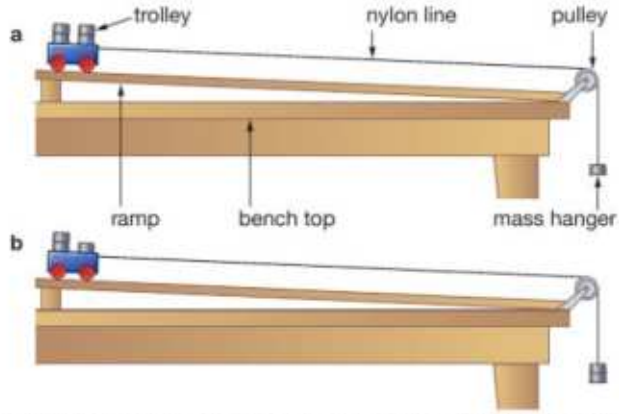
b Different-sized forces are applied to objects with the same mass. The small force produces a smaller acceleration than the large force.

▲ Figure 3.2 The acceleration of an object is affected by both its mass and the force applied to it.

INVESTIGATING FORCE, MASS AND ACCELERATION

The experiment shown in Figure 3.3 shows how the relationship between force, mass and acceleration can be investigated. It uses a trolley on a slightly sloping ramp. The slope of the ramp is adjusted so that the trolley keeps moving down it if you push it gently. The slope is intended to overcome the friction in the trolley's wheels that could affect the results.

Safety note: Heavy wooden runways need to be stacked and moved carefully. They are best used at low level rather than being placed on benches or tables where they may fall off. If heavy trolleys are used as 'vehicles', a 'catch box' filled with bubble wrap or similar material should be placed at the end of the runway.



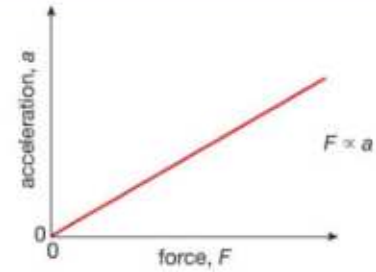
▲ Figure 3.3 You can use a trolley to find the acceleration caused by a particular force.

The force acting on the trolley is provided by the masses on the end of the nylon line. These masses accelerate as well as the trolley, so the force is increased by transferring one of the masses from the trolley to the mass hanger (Figure 3.3b). This increases the pulling force (explained later in this chapter) on the trolley, while keeping the total mass of the system the same.

The acceleration of the trolley can be measured by taking a series of pictures at equal time intervals using a digital video camera. Alternatively, a pair of **light gates** and a data logger can be used to find the speed of the trolley near the top of the ramp and near the end. The equation on page 495 can then be used to work out the acceleration.

EXTENSION WORK

The acceleration can be found using a digital video camera by measuring the distance travelled from the start for each image. Since the time between each image is known, a graph of displacement against time can be drawn. The gradient of the displacement–time graph gives the velocity at a particular instant, so data for a velocity–time graph can be obtained. The gradient of the velocity–time graph produced is the acceleration of the trolley.



▲ Figure 3.4 Force is proportional to acceleration.

Figure 3.4 shows a graph of force against acceleration when the mass of the trolley and hanging masses is constant and the accelerating force is varied.

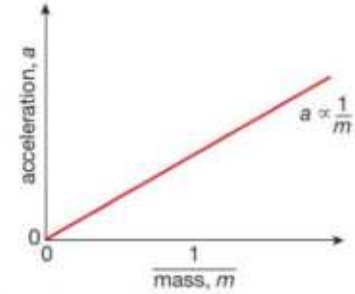
The graph is a straight line passing through the origin, which shows that:

force is proportional to acceleration

$$F \propto a$$

So doubling the force acting on an object doubles its acceleration.

In a second experiment, the accelerating force is kept constant and the mass of the trolley is varied.



▲ Figure 3.5 Acceleration is inversely proportional to mass.

Figure 3.5 shows the acceleration of the trolley plotted against $\frac{1}{m}$. This is also a straight line passing through the origin, showing that:

acceleration is **inversely proportional** to mass

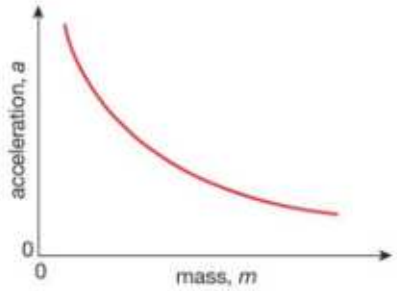
$$a \propto \frac{1}{m}$$

This means that for a given unbalanced force acting on an object, doubling the mass of the object will halve the acceleration.

Combining these results gives us:

force, F (N) = mass, m (kg) × acceleration, a (m/s^2)

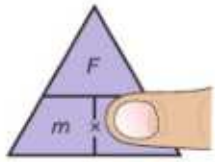
$$F = m \times a$$



▲ Figure 3.6 The graph of a against m is a curve. Plotting a against $\frac{1}{m}$ (while keeping the force constant) gives a straight line. This makes it easier to spot the way that a is affected by m.

Force is measured in newtons (N), mass is measured in kilograms (kg), and acceleration is measured in metres per second squared (m/s^2). From this we see that:

One newton is the force needed to make a mass of one kilogram accelerate at one metre per second squared.



▲ Figure 3.7 The equation can be rearranged using the triangle method. If you need to find the acceleration that results when a known force acts on an object of known mass, cover up a; you can see that $a = \frac{F}{m}$.

HINT

If an examination question asks you to write out the equation for calculating force, mass or acceleration, always give the actual equation (such as $F = m \times a$). You may not get the mark if you just draw the triangle.

DECELERATION IN A COLLISION

REMINDER

v is the final velocity, u is the initial velocity and t is the time for the change in velocity to take place.

REMINDER

The minus sign in Example 1 for velocity change indicates that the velocity has decreased.

If you are designing a car for high acceleration, the equation $F = ma$ tells you that the car should have low mass and the engine must provide a high accelerating force. You must also consider the force needed to stop the car.

When a moving object is stopped, it decelerates.

A negative acceleration is a deceleration.

If a large deceleration is needed then the force causing the deceleration must be large, too. Usually a car is stopped by using the brakes in a controlled way so that the deceleration is not excessive (too much). In an accident the car may collide with another vehicle or obstacle, causing a very rapid deceleration.

EXAMPLE 1

A car travelling at 20 m/s collides with a stationary lorry and stops completely in just 0.02 s. Calculate the deceleration of the car.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$ (see page 495)

$$a = \frac{v - u}{t}$$

$$= \frac{0\ \text{m/s} - 20\ \text{m/s}}{0.02\ \text{s}}$$

$$= \frac{-20\ \text{m/s}}{0.02\ \text{s}}$$

$$= -1000\ \text{m/s}^2$$

A person of mass 50 kg in the car experiences the same deceleration when she comes into contact with a hard surface in the car. This could be the dashboard or the windscreen. Calculate the force that the person experiences.

$$F = m \times a$$

$$= 50\ \text{kg} \times 1000\ \text{m/s}^2$$

$$= 50\,000\ \text{N}$$

FRICTION AND BRAKING



▲ Figure 3.8 Motorcycle disc brakes work using friction. Friction is necessary if we want things to stop.

The 'tread' of a tyre is the grooved pattern moulded into the rubber surface. It is designed to keep the rubber surface in contact with the road by throwing water away from the tyre surface.

Brakes on cars and bicycles work by increasing the friction between the **rotating** wheels and the body of the vehicle, as shown in Figure 3.8.

The friction force between the tyres and the road depends on the condition of the tyres and the surface of the road. It also depends on the weight of the vehicle. If the tyres have a good tread, are properly inflated (filled with air) and the road is dry, the friction force between the road and the tyres will be at its maximum.

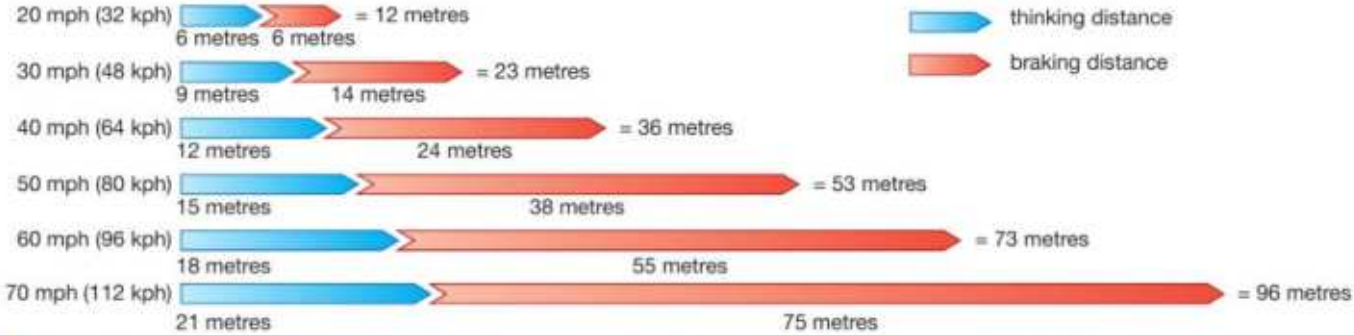
Unfortunately, we do not always travel in ideal conditions. If the road is wet or the tyres are in bad condition the friction force will be smaller. If the brakes are applied too hard, the tyres will not grip the road surface and the car will skid (slide out of control). Once the car is skidding the driver no longer has control and it will take longer to stop. Skidding can be avoided by applying the brakes in the correct way, so that the wheels do not lock. Most modern cars are fitted with ABS (anti-lock braking system) to reduce the chance of a skid occurring. ABS is a computer-controlled system that senses when the car is about to skid and releases the brakes for a very short time.

SAFE STOPPING DISTANCE

The Highway Code used in the United Kingdom gives stopping distances for cars travelling at various speeds. The stopping distance is the sum of the thinking distance and the braking distance. The faster the car is travelling the greater the stopping distance will be.

THINKING DISTANCE

When a driver suddenly sees an object blocking the way ahead, it takes time for him or her to respond to the new situation before taking any action, such as braking. This time is called reaction time and will depend on the person driving the car. It will also depend on a number of other factors including whether the driver is tired or under the influence of alcohol or other drugs that slow reaction times. Poor visibility (for example, fog) may also make it difficult for a driver to identify a danger and so cause him or her to take longer to respond. Clearly, the longer the driver takes to react, the further the car will travel before braking even starts – that is, the longer the thinking distance will be. Equally clear is the fact that the higher the car's speed, the further the car will travel during this 'thinking time'. If the distance between two cars is not at least the thinking distance then, in the event of an emergency stop by the vehicle in front, a violent accident is inevitable.



▲ Figure 3.9 The stopping distance is the distance the car covers from the moment the driver is aware of the need to stop to the point at which the vehicle comes to a complete stop.

BRAKING DISTANCE

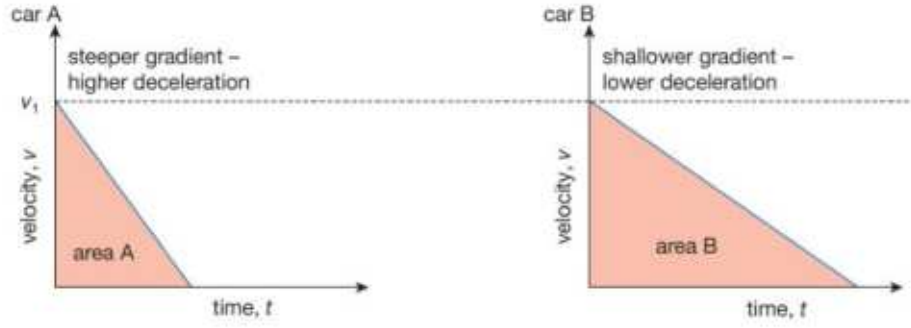
With ABS (anti-lock braking system) braking, in an emergency you brake as hard as you can. This means that the braking force will be a maximum and we can work out the deceleration using the equation below.

$F = m \times a$, rearranged to give:

$a = \frac{F}{m}$ (shown in Figure 3.7)

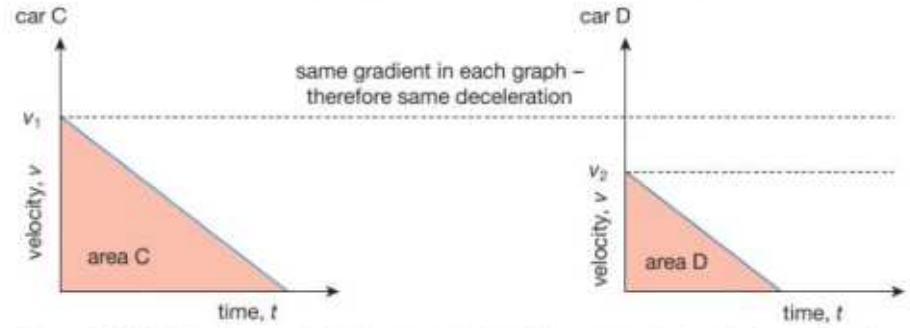
It is worth pointing out here that vehicles with large masses, like lorries, will have smaller rates of deceleration for a given braking force – they will, therefore, travel further while braking.

Chapter 1 shows that the distance travelled by a moving object can be found from its velocity–time graph. The area under the graph gives the distance travelled. Look at the velocity–time graphs in Figures 3.10 and 3.11.



▲ Figure 3.10 Velocity–time graphs for two cars braking at different rates from the same speed, v_1, to rest.

Figure 3.10 shows two cars, A and B, braking from the same velocity. Car A is braking harder than car B and comes to rest in a shorter time. Car B travels further before stopping, as you can see from the larger area under the graph. Remember that the maximum rate of deceleration depends on how hard you can brake without skidding – in poor conditions the braking force will be lower.



▲ Figure 3.11 Velocity–time graphs for two cars braking at the same rate to rest, from different speeds, v_1 and v_2.

Figure 3.11 shows two cars, C and D, braking at the same rate, as you can see from the gradients. Car C is braking from a higher velocity and so takes longer to stop. Again, the greater area under the graph for car C shows that it travels further while stopping than car D.

Vehicles cannot stop instantly! Remember also that the chart in Figure 3.9 shows stopping distances in ideal conditions. If the car tyres or brakes are in poor condition, or if the road surface is wet, icy or slippery, then the car will travel further before stopping.

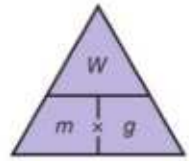
WEIGHT

The weight of an object is the force that acts on it because of gravity. The weight of an object depends on its mass and the strength of gravity. The **gravitational field strength** (g) is the force that acts on each kilogram of mass. We can work out the weight of an object by using this equation:

weight, W (N) = mass, m (kg) × gravitational field strength, g (N/kg)

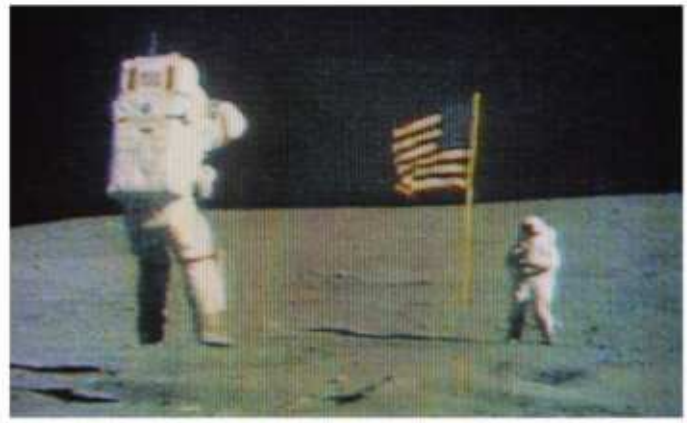
$$W = m \times g$$

You can use the triangle method to rearrange this equation.



▲ Figure 3.12 Rearranging $W = m \times g$ using the triangle method

Near and on the Earth's surface the gravitational field strength is approximately 9.8 N/kg, but we often use 10 N/kg to make calculations easier. The gravitational field strength on the Moon is about 1.6 N/kg, so an object taken from the Earth to the Moon will have less weight even though it has the same mass.



▲ Figure 3.13 An astronaut jumping on the Moon enjoying the effect of low gravity

EXAMPLE 2

An astronaut in a space suit with a complete life support pack has a mass of 140 kg. How much will the astronaut weigh **a** on the Earth, and **b** on Mars where the gravitational field strength is about one third of that on Earth? (Take the strength of the Earth's gravitational field as 10 N/kg.)

The force of gravity or weight of an object is given by:

weight, W = mass, m × gravitational field strength, g

a weight on Earth = 140 kg × 10 N/kg

= 1400 N

b g on Mars = $\frac{10\ \text{N/kg}}{3}$ = 3.34 N/kg

weight on Mars = 140 kg × 3.34 N/kg

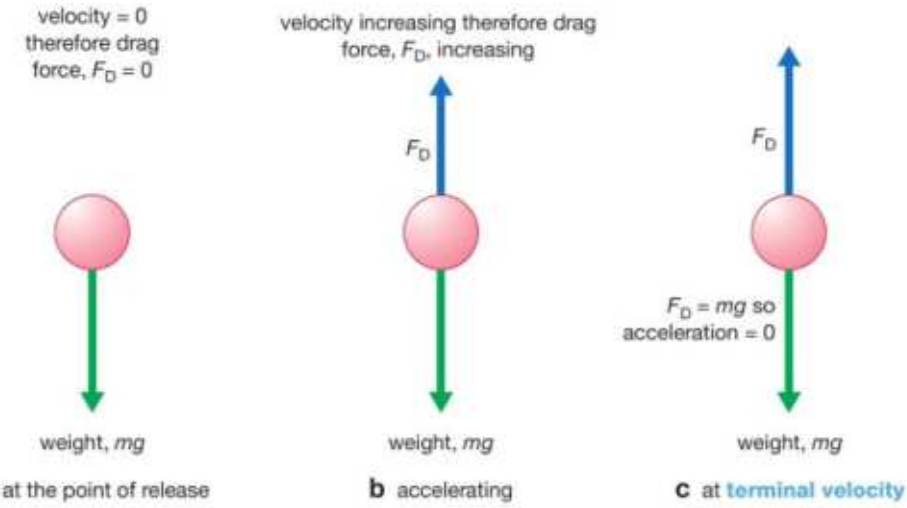
= 468 N

AIR RESISTANCE AND TERMINAL VELOCITY

An object moving through air experiences a force that opposes its movement. This force is called air resistance or drag. The size of the drag force acting on an object depends on its shape and its speed. Cars are designed to have a low **drag coefficient**. The drag coefficient is a measure of how easily an object moves through the air. High-speed trains have an efficient streamlined shape so that air flows more smoothly around them. Streamlined, smooth surfaces produce less drag.

It is particularly important to make fast-moving objects streamlined because the drag force increases with the speed of the object. The fact that drag increases with speed affects the way that dropped objects accelerate, because the faster they move the greater the drag force opposing their motion becomes.

Objects falling through the air experience two significant forces: the weight force (that is, the pull of gravity on the object) and the opposing drag force.

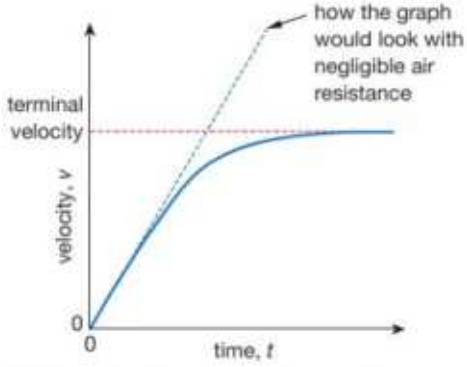


▲ Figure 3.14 How the forces acting on a object change as its velocity changes

In Figure 3.14a the object has just been released and has a starting velocity of 0 m/s. This means that there is no drag. (Remember that the drag force acts on moving objects.) The resulting downward-acting force is just the weight force. This force makes the object accelerate towards the Earth.

Figure 3.14b shows the object now moving. Because it is moving it has a drag force, F_D, acting on it. The drag force acts upwards (up) against the movement. This means that the resulting downward force (acting down) on the object is $(mg - F_D)$. You can see that the drag force has made the resulting downward force smaller, so the acceleration is smaller. All the time that the object is accelerating it is getting faster. The faster the object moves the bigger the drag force is.

In Figure 3.14c the drag force has increased to the point where it exactly balances the weight force – since there is now no unbalanced force on the object its acceleration is also zero. The object has reached its terminal velocity and although it is still falling it will not get any faster. Figure 3.15 shows a velocity–time graph for an object falling through air and reaching terminal velocity.



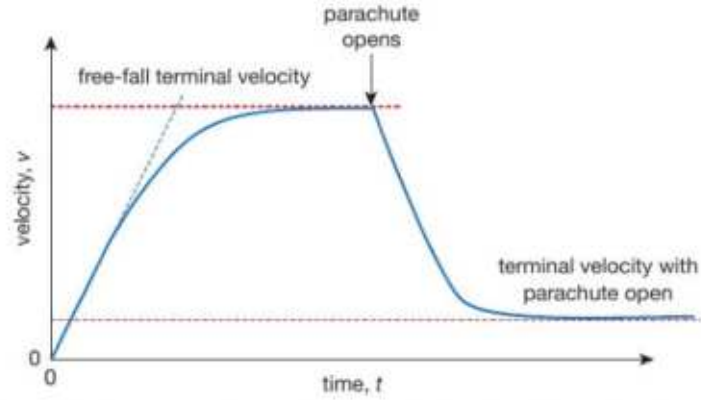
▲ Figure 3.15 The velocity–time graph for an object accelerating until it reaches terminal velocity

PARACHUTES



▲ Figure 3.16 These skydivers have just left the aeroplane. They will accelerate until they reach terminal velocity.

When a skydiver jumps from a plane she will accelerate for a time and eventually reach terminal velocity. Typically this will be between 150 and 200 kph. When she opens her parachute this will cause a sudden increase in the drag force. At this velocity (around 200 kph) the drag force of the parachute is greater than the weight of the skydiver. This means that the unbalanced force acting on the parachutist acts upwards and, for a while, she will decelerate. As she slows down the size of the drag force decreases and, eventually, a new terminal velocity is reached. Obviously the new terminal velocity depends on the design of the parachute, but it must be slow enough to allow the parachutist to land safely. Figure 3.17 shows a velocity–time graph for a skydiver.



▲ Figure 3.17 Velocity–time graph for a free-fall parachutist reaching terminal velocity, then opening the parachute

MODELLING TERMINAL VELOCITY

Objects have to accelerate to quite high speeds in air to reach terminal velocity. This makes demonstrating the effect in a laboratory difficult. However, objects falling through liquids also experience a drag force that increases with speed. The sizes of drag forces in liquids are much higher than in gases. This means that objects falling through liquids have a much lower terminal velocity than objects falling through air, and can be used to model terminal velocity. You can use a tall measuring cylinder filled with water and drop small-**diameter** (1–2 mm) glass balls into it. Alternatively, use a much thicker liquid like oil and use small-diameter balls. As well as demonstrating terminal velocity this presents plenty of opportunities for investigations. You could measure the terminal velocity using a light gate and a data logger.

LOOKING AHEAD – WEIGHTLESSNESS



▲ Figure 3.18 Scientists in the International Space Station experience weightlessness



▲ Figure 3.19 Astronauts training for weightlessness in an aircraft

Figures 3.18 and 3.19 show astronauts in 'weightless' conditions in the International Space Station and training for weightlessness in an aircraft. In both cases the astronauts are still being pulled towards the Earth by gravity. They all experience the force we call weight, calculated using the equation *mg* that we met earlier in Chapter 3, yet they appear to float freely!

They are in a condition called free-fall. You may have noticed feeling very slightly 'lighter' when you are in a lift as it accelerates downwards. This effect is more noticeable if the lift accelerates at a greater rate. Further study of physics will explain all this.

Exploring the Solar System

Sir Isaac Newton worked out his laws of motion more than 300 years ago. Although Albert Einstein explained that these laws do not hold when objects are travelling at speeds close to the speed of light (3×10^8 m/s), Newton's laws give answers to calculations accurate enough for scientists to plan successful space missions like the Moon landing in 1969, the Phoenix lander to Mars in 2007 and the incredible achievement of landing the Philae lander (carried by the Rosetta spacecraft) on a **comet** in 2014.

CHAPTER QUESTIONS

More questions on force and acceleration can be found at the end of Unit 1 on page 526.

SKILLS CRITICAL THINKING

1 Explain what is meant by an unbalanced force? Illustrate your answer with an example.

SKILLS REASONING

2 Rockets burn fuel to give them the thrust needed to accelerate. As the fuel burns the mass of the rocket gets smaller. Assuming that the rocket motors provide a constant thrust force, explain what will happen to the acceleration of the rocket as it burns its fuel.

SKILLS PROBLEM SOLVING

3 a Calculate the force required to make an object of mass 500 g accelerate at 4 m/s^2. (Take care with the units!)

b An object accelerates at 0.8 m/s^2 when a resultant force of 200 N acts upon it. Calculate the mass of the object.

c What acceleration is produced by a force of 250 N acting on a mass of 25 kg?

SKILLS CRITICAL THINKING

4 Explain the meaning of the following terms used to describe stopping vehicles in an emergency:

a thinking distance

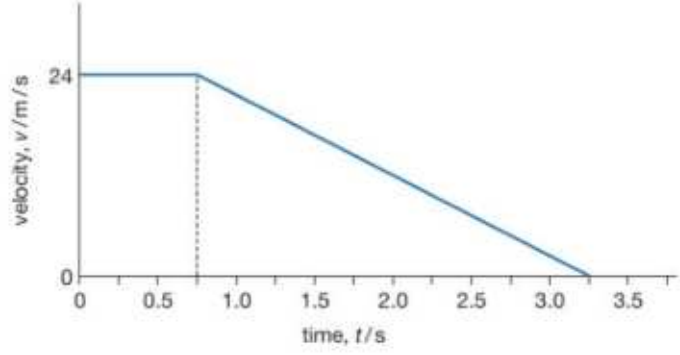
b braking distance

c overall stopping distance.

5 What factors affect the braking distance of a vehicle?

SKILLS ANALYSIS

6 The diagram below shows the velocity–time graph for a car travelling from the moment that the driver sees an object blocking the road ahead.



Use the graph to find out:

a how long the driver takes to react to seeing the obstacle (reaction time)

b how far the car travels in this reaction time

c how long it takes to bring the car to a halt once the driver starts braking

d the total distance the car travels before stopping.

SKILLS PROBLEM SOLVING

7 Calculate the weight of an apple of mass 100 grams:

a on the Earth (g = 10 N/kg)

b on the Moon (g = 1.6 N/kg).

SKILLS CRITICAL THINKING

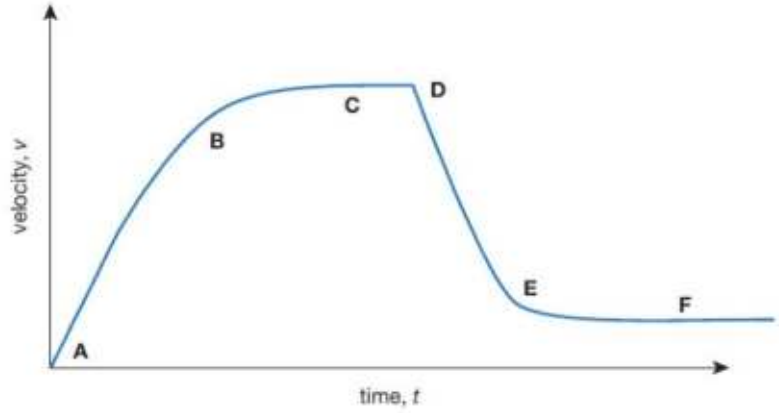
8 What factors affect the drag force that acts on a high-speed train?

SKILLS DECISION MAKING

9 Describe an experiment to demonstrate terminal velocity. Say what measurements you need to take in your experiment to show that a falling object has reached terminal speed.

SKILLS ANALYSIS

10 Look at the velocity–time graph for a free-fall parachutist shown below.



State and explain the direction and relative size of the unbalanced force acting on the parachutist at each of the points A–F labelled on the graph.

UNIT QUESTIONS

SKILLS CRITICAL THINKING 6th

1

a Which of the following quantities is not a vector quantity?

A force **B** area **C** displacement **D** velocity **(1)**

b Which of the following quantities is not a scalar quantity?

A speed **B** your age **C** volume **D** acceleration **(1)**

c Which of the following statements about the motion of an object on which unbalanced forces act is false?

A The object could continue moving at constant speed in a straight line.

B The object could accelerate.

C The object could slow down.

D The object could change the direction in which it is moving. **(1)**

d A ball is thrown vertically upwards in the air. Which of the following statements about the motion of the ball is false?

A The ball will be travelling as fast as it was when it gets back to the ground as it was when first thrown upwards.

B The ball will be stationary for an instant at the highest point in its flight.

C The direction of the force on the ball changes so the ball falls back to the ground.

D The direction of the acceleration is always downwards. **(1)**

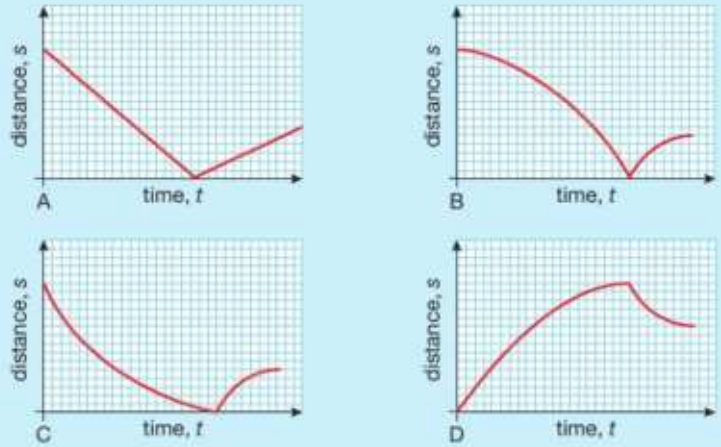
(Total 4 marks)

SKILLS ANALYSIS

2

A tennis ball is dropped from a height of 3 m and bounces back to a height of 1 m after hitting the ground ($s = 0$).

a Which of the following distance–time graphs shows this motion correctly? **(1)**



SKILLS CRITICAL THINKING 7th

SKILLS PROBLEM SOLVING 8th

b i Explain the difference between the terms distance and displacement. **(2)**

ii What is the displacement of the tennis ball at the end of the described motion? **(1)**

SKILLS PROBLEM SOLVING

c i Use the equation $v^2 = u^2 + 2as$ to calculate the velocity of the tennis ball when it hits the ground. **(4)**

ii What is the average speed of the tennis ball while it is falling to the ground? **(2)**

iii Calculate how long it takes for the tennis ball to reach the ground. **(2)**

SKILLS CRITICAL THINKING

d How can the distance travelled by the tennis ball be found from a velocity–time graph of its motion? **(1)**

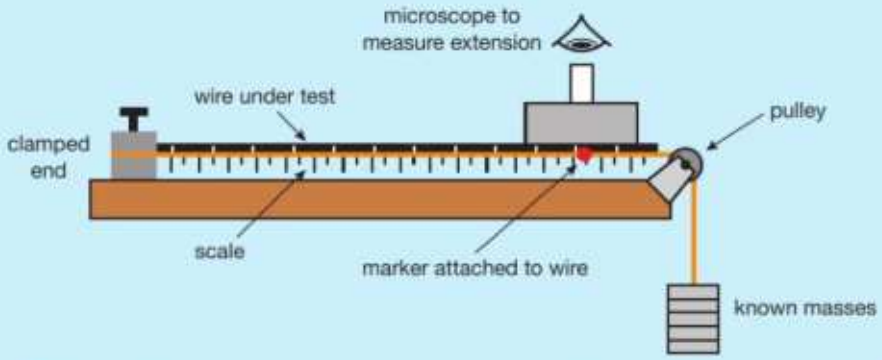
SKILLS INTERPRETATION

e Sketch a velocity–time graph for the tennis ball from the time that it is released to the time that it has rebounded to 1 m after the first bounce. Assume that the time that the ball is in contact with the ground is negligible (too short to show on your graph). Include as much numerical detail as you can without doing any further calculations. **(6)**

(Total 19 marks)

SKILLS CRITICAL THINKING

3 A student uses the following piece of apparatus to investigate how the extension of a length of wire varies with the force applied to it.



a i Name the independent variable in this investigation. **(1)**

ii Name the dependent variable in this investigation. **(1)**

iii Name one control variable in this investigation. **(1)**

b How is the force being applied to the wire calculated? **(1)**

SKILLS DECISION MAKING

c Explain how the student should use the apparatus to determine if the wire obeys Hooke's law. **(5)**

SKILLS EXECUTIVE FUNCTION

d The student also wants to know if the sample behaves elastically. Explain how the student can improve the investigation and discover whether or not the wire behaves elastically. **(3)**

(Total 12 marks)

PHYSICS UNIT 2 ELECTRICITY

It is sometimes really difficult to imagine how we could live without electricity. As we mmove around we use electricity from batteries and cells for our mobile phones, mp3 players and other mobile devices. In our homes and other buildings we use electricity from the mains for heating, lighting and providing the energy for household appliances such as televisions, radios, computers and their printers. Understanding what electricity is, where it comes from and how we can control it is important if we are to make maximum use of this important source of energy.



4 MAINS ELECTRICITY

The electricity that we use for heating, lighting and air conditioning in our homes is called mains electricity and is supplied to us by power stations.

In this chapter you will learn how mains electricity is brought to our homes and supplied to our appliances. You will also read about devices that protect us from electrical shocks.



▲ Figure 4.1 Most household appliances use mains electricity as their source of energy.

LEARNING OBJECTIVES

- Understand how the use of insulation, double insulation, earthing, fuses and circuit breakers protects the device or user in a range of domestic appliances
- Understand why a current in a resistor results in the electrical transfer of energy and an increase in temperature, and how this can be used in a variety of domestic contexts
- Know and use the relationship between power, current and voltage:

  power = current × voltage

  $P = I \times V$

  and apply the relationship to the selection of appropriate fuses
- Know the difference between mains electricity being alternating current (a.c.) and direct current (d.c.) being supplied by a cell or battery
- Use the relationship between energy transferred, current, voltage and time:

  energy transferred = current × voltage × time

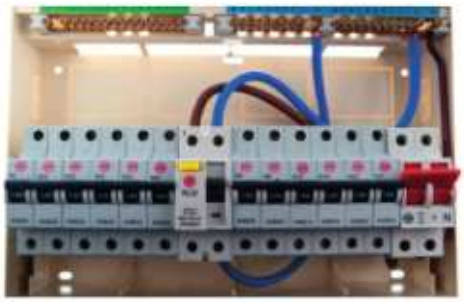
  $E = I \times V \times t$

UNITS

In this unit, you will need to use ampere (A) as the unit of current, coulomb (C) as the unit of charge, joule (J) as the unit of energy, ohm (Ω) as the unit of resistance, second (s) as the unit of time, volt (V) as the unit of voltage and watt (W) as the unit of power.

When you turn on your computer, television and most other appliances in your home the electricity you use is almost certainly going to come from the mains supply. This electrical energy usually enters our homes through an underground cable. The cable is connected to an electricity meter, which measures the amount of electrical energy used. From here, the cable is connected to a consumer unit or a fuse box, which contains fuses or circuit breakers for the various **circuits** in your home. Fuses and circuit breakers are safety devices which shut off the electricity in a circuit if the current in them becomes too large (see page 531).

Most of the wires that leave the fuse box are connected to ring main circuits that are hidden in the walls or floors around each room. Individual pieces of electrical equipment are connected to these circuits using plugs.



▲ Figure 4.2 Circuit breakers in a consumer unit

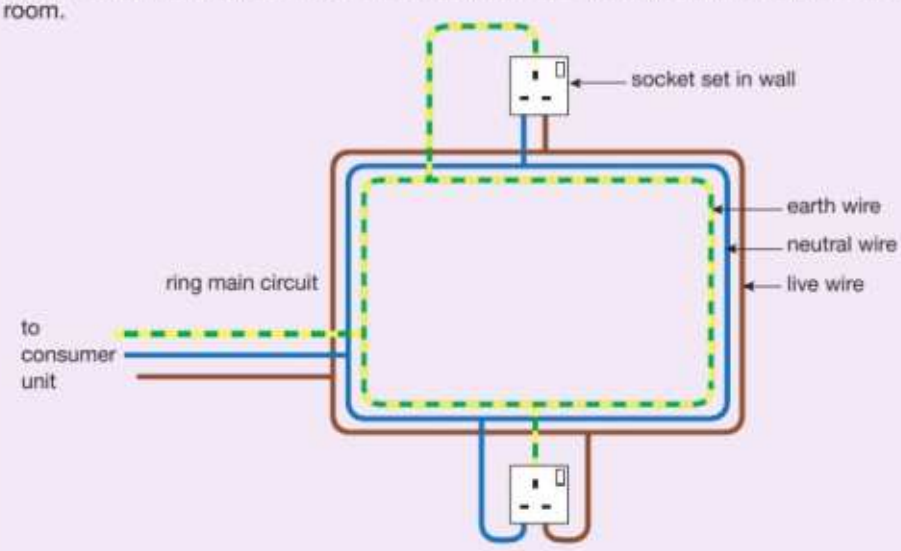
Ring main circuits usually consist of three wires – the live wire, the neutral wire and the earth wire.

The live wire provides the path along which the electrical energy from the power station travels. The neutral wire completes the circuit.

The earth wire usually has no current in it. It is there to protect you if an appliance develops a fault (see page 531). It provides a path for current to escape without passing through the user.

EXTENSION WORK

Ring main circuits provide a way of allowing several appliances in different parts of the same room to be connected to the mains using the minimum amount of wiring. Imagine how much wire would be needed if there was just one mains socket in each room.



▲ Figure 4.3 Ring main circuits help to cut down on the amount of wiring needed in a house.

Plugs and sockets in different countries look different, but the principles (rules) of electrical wiring are similar.

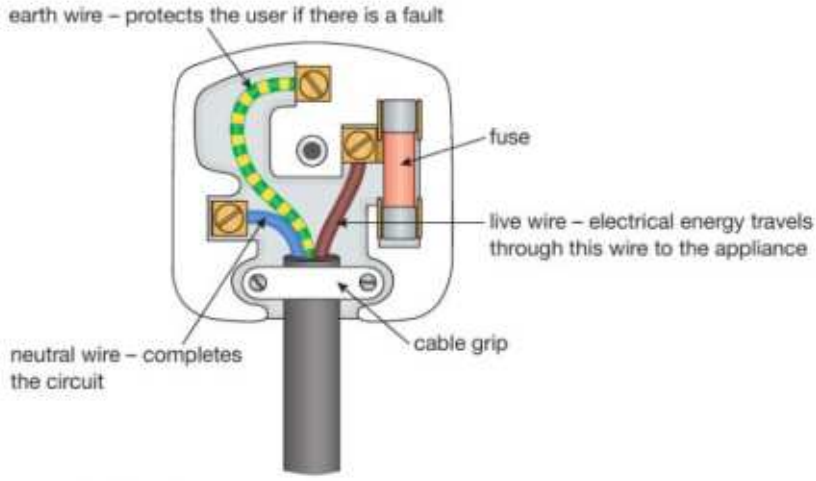




▲ Figure 4.4 Plug sockets in the UK and in Portugal

The mains electricity supplied to homes in the UK, China, India and many other countries is between 220 V and 240 V. This is a much higher **voltage** than the **cells** and batteries used in mobile electrical appliances. If you come into direct contact with mains electricity you could receive a severe electric shock, which might even be fatal. To prevent this the outer part of a plug, called the casing, is made from plastic, which is a good **insulator**.

Connections to the circuits are made via three brass pins, as the metal brass is an excellent **conductor** of electricity. Figure 4.5 shows the inside of a 3-pin plug used in the UK, but similar principles apply to all kinds of plug all over the world.



▲ Figure 4.5 A labelled plug

SAFETY DEVICES

FUSES

Many plugs contain a fuse. The fuse is usually in the form of a cylinder or cartridge, which contains a thin piece of wire made from a metal that has a low melting point. If there is too large a current in the circuit the fuse wire becomes very hot and melts. The fuse 'blows'. The circuit is now incomplete so there is no current. This prevents you getting a shock and reduces the possibility of an electrical fire. Once the fault causing the increase in current has been corrected, the blown fuse must be replaced with a new one of the same size before the appliance can be used again.



circuit symbol for a fuse

There are several sizes of fuses. The most common for domestic appliances in the UK are 3 A, 5 A and 13 A. The correct fuse for a circuit is the one that allows the correct current but blows if the current is a little larger. If the correct current in a circuit is 2 A then it should be protected with a 3 A fuse. If the correct current is 4 A then a 5 A fuse should be used. It is possible to calculate the correct size of fuse for an appliance but nowadays manufacturers provide appliances already fitted with the correct size of fuse.

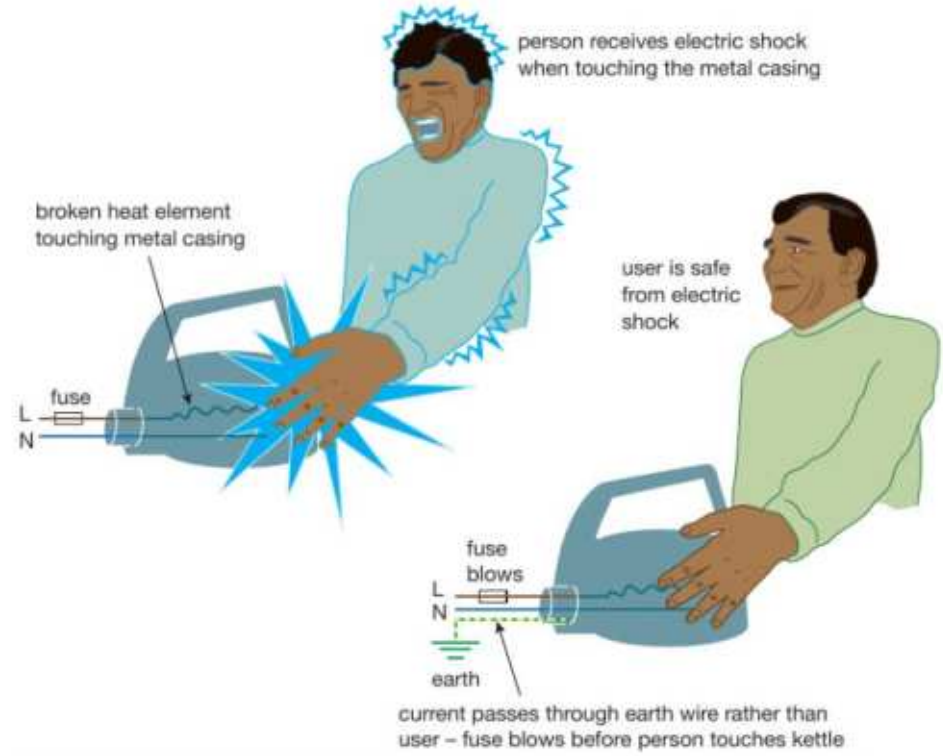


▲ Figure 4.6 Fuses are important safety devices in electrical appliances.

Modern safety devices, such as those you might find in your consumer unit, are often in the form of trip switches or circuit breakers. If too large a current flows in a circuit a switch automatically opens making the circuit incomplete. Once the fault in the circuit has been corrected, the switch is reset, usually by pressing a reset button. There is no need for the switch or circuit breaker to be replaced, as there is when fuses are used. The consumer unit shown in Figure 4.2 uses circuit breakers.

EARTH WIRES AND DOUBLE INSULATION

Many appliances have a metal casing. This should be connected to the earth wire so that if the live wire becomes damaged or breaks and comes into contact with the casing the earth wire provides a low-resistance path for the current. This current is likely to be large enough to blow the fuse and turn the circuit off. Without the earth wire anyone touching the casing of the faulty appliance would receive a severe electric shock as the current passed through them to earth (Figure 4.7).



▲ Figure 4.7 The earth wire provides protection when electrical appliances develop a fault.

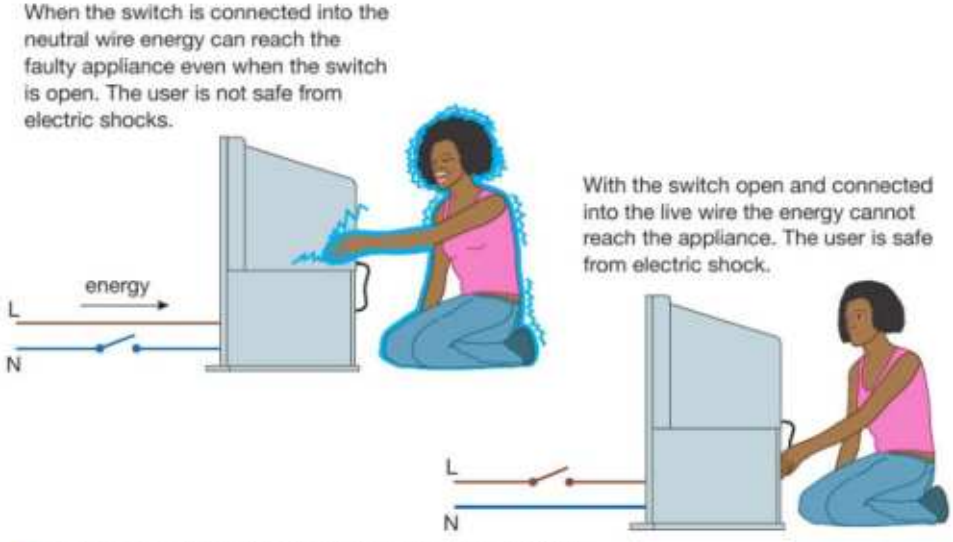


▲ Figure 4.8 This plastic kettle has double insulation which means that there is no need for an earth wire.

Some modern appliances now use casings made from an insulator such as plastic rather than from metal. If all the electrical parts of an appliance are insulated in this way, so that they cannot be touched by the user, the appliance is said to have double insulation. Appliances that have double insulation use a two-wire **flex**. There is no need for an earth wire.

SWITCHES

Switches in mains circuits should always be placed in the live wire so that when the switch is open no energy in the form of electricity can reach an appliance. If the switch is placed in the neutral wire, energy can still enter a faulty appliance, and could possibly cause an electric shock (Figure 4.9).



▲ Figure 4.9 The switch in a circuit should be in the live wire.

THE HEATING EFFECT OF CURRENT



▲ Figure 4.10 The wires inside a toaster have a high resistance. They become very hot when a current passes through them.

The wiring in a house is designed to let current pass through it easily. As a result, the wires do not become warm when appliances are being used. We say that the wires have a low **resistance**. However, in some appliances, for example, kettles or toasters (Figure 4.10), we want wires (more usually called **heating elements**) to become warm. The wires of a heating element are designed to have a high resistance so that as the current passes through them energy is transferred and the element heats up. We use this heating effect of current in many different ways in our homes. You will learn more about resistance in Chapter 6.

Other common appliances that make use of the heating effect of electricity include kettles, dishwashers, electric cookers, washing machines, electric fires and hairdryers.

When current passes through the very thin wire (**filament**) of a traditional light bulb it becomes very hot and **glows** (shines) white. The bulb is transferring electrical energy to heat and light energy.

EXTENSION WORK

Incandescent bulbs like these are very inefficient. Often more than 90% of the energy transferred is lost to the surroundings as heat. As a result they are rapidly being replaced by modern halogen bulbs and LEDs, which give off much less heat and therefore waste less energy.



▲ Figure 4.11 It is the heating effect of a current that is causing this bulb to glow.

ELECTRICAL POWER

Figure 4.12 shows a 50 W **halogen light bulb**. You can also buy 70 W light bulbs. Both bulbs transfer electrical energy to heat and light. The 70 W bulb will be brighter because it transfers 70 J of electrical energy every second. The dimmer 50 W halogen bulb shown transfers only 50 J of energy every second. A 70 W bulb has a higher power rating.



▲ Figure 4.12 The dimmer 50 W bulb transfers less electrical energy to heat and light energy every second.

KEY POINT

You will learn more about voltage and current in Chapter 5.

Power is measured in joules per second or watts (W).

Devices that transfer lots of energy very quickly have their power rating expressed in kilowatts (kW).

1 kW = 1000 W

The power (P) of an appliance is related to the voltage (V) across it and the current (I) flowing through it.

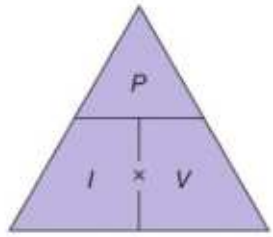
The equation is:

power, P (watts) = current, I (amps) × voltage, V (volts)

$$P = I \times V$$

HINT

If an examination question asks for the equation for calculating power, voltage or current, always give the actual equation (such as $P = I \times V$). You may not be awarded a mark if you just draw the triangle.



▲ Figure 4.13 You can use the triangle method for rearranging equations like $P = I \times V$.

EXAMPLE 1

A 230 V television takes a current of 3 A. Calculate the power of the television.

$$P = I \times V$$
$$= 3\text{ A} \times 230\text{ V}$$
$$= 690\text{ W}$$

EXAMPLE 2

Calculate the correct fuse that should be used for a 230 V, 1 kW electric hairdryer.

$$I = \frac{P}{V}$$
$$= \frac{1000\text{ W}}{230\text{ V}}$$
$$= 4.35\text{ A}$$

The correct fuse for this hairdryer is therefore a 5 A fuse.

CALCULATING THE TOTAL ENERGY TRANSFERRED BY AN APPLIANCE

The power of an appliance (P) tells you how much energy it transfers each second. This means that the total energy (E) transferred by an appliance is equal to its power multiplied by the length of time (in seconds) the appliance is being used.

energy, E (joules) = power, P (watts) × time, t (seconds)

$$E = P \times t$$

or since $$P = I \times V$$

$$E = I \times V \times t$$

EXAMPLE 3

Calculate the energy transferred by a 60 W bulb that is turned on for **a** 20 s, and **b** 5 min.

a $E = P \times t$

$= 60\ \text{W} \times 20\ \text{s}$

$= 1200\ \text{J}$ or $1.2\ \text{kJ}$

b $E = P \times t$

$= 60\ \text{W} \times 5 \times 60\ \text{s}$

$= 18\,000\ \text{J}$ or $18\ \text{kJ}$

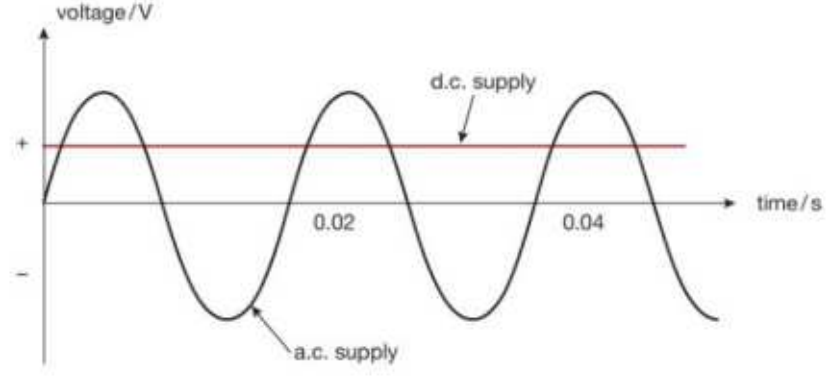
ALTERNATING CURRENT AND DIRECT CURRENT

If we could see the current or voltage from the mains it would appear to be very strange. Its value increases and then decreases and then does the same again but in the opposite direction. If we could draw these changes as a graph they would look like a wave.

This happens because of the way in which the electricity is generated at the power station. A current or voltage that behaves like this is called an alternating current (a.c.) or **alternating voltage**. This is very different to the currents and voltages we get from batteries and cells.

Cells and batteries provide currents and voltages that are always in the same direction and have the same value. This is called direct current (d.c.) or direct voltage. If we drew this as a graph it would be a straight horizontal line.

Figure 4.14 shows how the voltage of an a.c. supply compares with the voltage of a d.c. supply.



▲ Figure 4.14 How the voltage of an a.c. supply compares with that of a d.c. supply

CHAPTER QUESTIONS

More questions on domestic electricity can be found at the end of Unit 2 on page 554.

SKILLS PROBLEM SOLVING

1 a There is a current of 0.25 A in a bulb when a voltage of 12 V is applied across it. Calculate the power of the bulb.

b Calculate the voltage that is being applied across a 10 W bulb with a current of 0.2 A.

c Calculate the current in a 60 W bulb if the voltage across it is 230 V.

d How much energy is transferred if a 100 W bulb is left on for 5 hours?

SKILLS CRITICAL THINKING

2 An electric kettle is marked '230 V, 1.5 kW'.

a Explain what these numbers mean.

SKILLS PROBLEM SOLVING

b Calculate the correct fuse that should be used.

SKILLS REASONING

c Explain why a 230 V, 100 W bulb glows more brightly than a 230 V, 60 W bulb when both are connected to the mains supply.

SKILLS CRITICAL THINKING

3 a Give one advantage of using a circuit breaker rather than a wire or cartridge fuse.

b Why is the switch for an appliance always placed in the live wire?

c What is meant by the sentence 'The hairdryer has double insulation'?

SKILLS DECISION MAKING, CREATIVITY

4 Think of a room in your house where there are lots of electrical appliances. Make a list of them. Now organise your list so that the appliances that you think have the highest power rating are at the top of your list and those with the lowest are at the bottom. How could you discover if your guesses are correct?

5 CURRENT AND VOLTAGE IN CIRCUITS

We rely on electricity in many areas of our lives. This chapter looks at what electric current is. You will learn what happens to electric current in different circuits, and what effect it has.

Look around the room you are in. If you are at home, you will probably be able to see a television, a radio or a computer. If you are in a science laboratory, you may be able to see a projector, a power supply or lights in the ceiling. These and many other everyday objects need electric currents if they are to work. But what are electric currents? How are they produced and what do they do in a circuit?



▲ Figure 5.1 The gas in this tube glows when there is a current.

LEARNING OBJECTIVES

- Explain why a series or parallel circuit is more appropriate for particular applications, including domestic lighting
- Know that electric current in solid metallic conductors is a flow of negatively charged electrons
- Know and use the relationship between voltage, current and resistance:

  voltage = current × resistance

  $V = I \times R$
- Know that current is the rate of flow of charge
- Know and use the relationship between charge, current and time:

  charge = current × time

  $Q = I \times t$
- Know that lamps and LEDs can be used to indicate the presence of a current in a circuit
- Know that the voltage across two components connected in parallel is the same
- Know that voltage is the energy transferred per unit charge passed
- Know and use the relationship between energy transferred, charge and voltage:

  energy transferred = charge × voltage

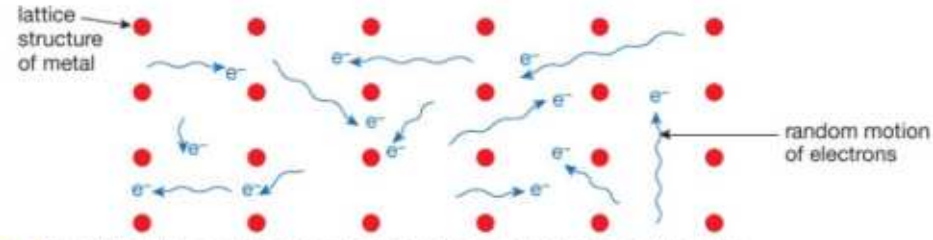
  $E = Q \times V$
- Know that the volt is a joule per coulomb
- Understand why current is conserved at a junction in a circuit

CONDUCTORS, INSULATORS AND ELECTRIC CURRENT

An electric current is a flow of charge. In metal wires the charges are carried by very small particles called electrons.

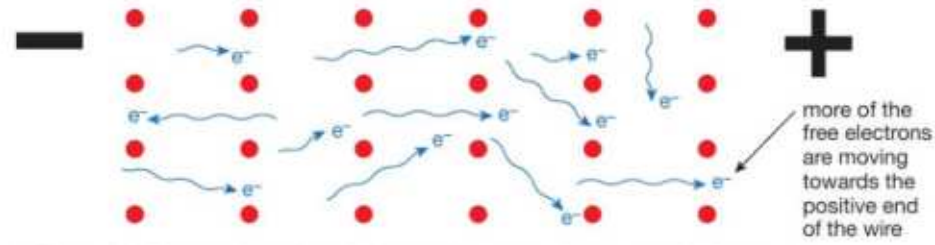
Electrons flow easily through all metals. We therefore describe metals as being good conductors of electricity. Electrons do not flow easily through plastics – they are poor conductors of electricity. A very poor conductor is known as an insulator and is often used in situations where we want to prevent the flow of charge – for example, in the casing of a plug.

In metals, some electrons are free to move between the **atoms**. Under normal circumstances this movement is random – that is, the number of electrons flowing in any one direction is roughly equal to the number flowing in the opposite direction. There is therefore no overall flow of charge.



▲ Figure 5.2a With no voltage there is an equal flow of electrons in all directions.

If, however, a cell or battery is connected across the conductor, more of the electrons now flow in the direction away from the negative terminal and towards the positive terminal than in the opposite direction. We say 'there is now a net flow of charge'. This flow of charge is what we call an electric current.



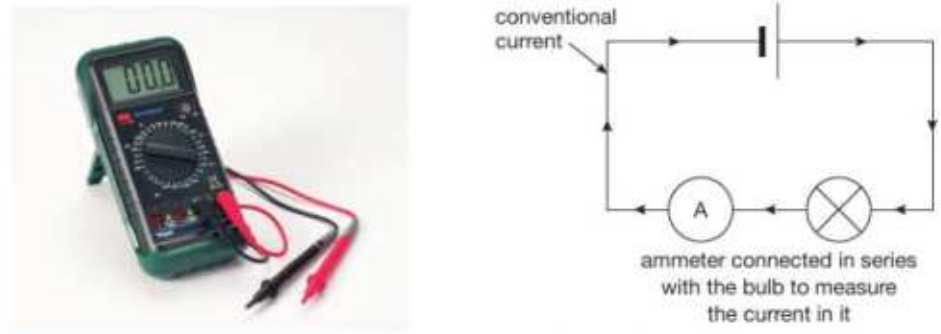
▲ Figure 5.2b When a voltage is applied more electrons will move towards the positive.

In insulators, all the electrons are held tightly in position and are unable to move from atom to atom. Charges are therefore unable to move through insulators.

EXTENSION WORK

When scientists first experimented with charges flowing through wires, they assumed that it was positive charges that were moving and that current travels from the positive to the negative. We now know that this is incorrect and that when an electric current passes through a wire it is the negative charges or electrons that move. Nevertheless when dealing with topics such as circuits and motors, it is still considered that electrons flow from positive to negative. This is conventional current.

MEASURING CURRENT



▲ Figure 5.3 An ammeter is used to measure current in a circuit. It has a very low resistance and so has almost no effect on the current.

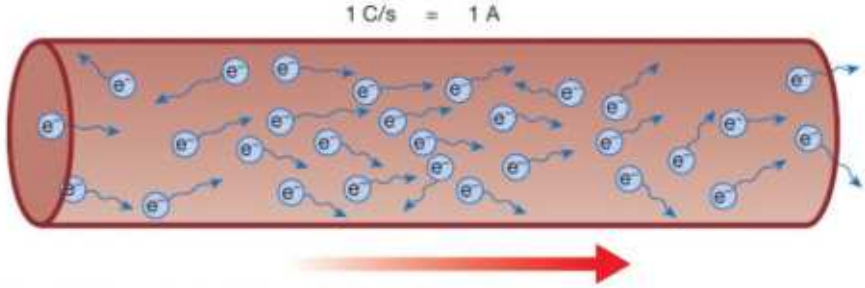
We measure the size of the current in a circuit using an ammeter. The ammeter is connected in series (see page 542) with the part of the circuit we are interested in.

The size of an electric current indicates the rate at which the charge flows.

The charge carried by one electron is very small and would not be a very useful measure of charge in everyday life. It would be a little like asking how far away the Moon is from the Earth … and getting the answer in mm!

To avoid this problem we measure electric charge (Q) in much bigger units called coulombs (C). One coulomb of charge is equal to the charge carried by approximately six million, million, million (6×10^{18}) electrons.

We measure electric current (I) in amperes or amps (A). If there is a current of 1 A in a wire it means that 1 C of charge is passing along the wire each second.



▲ Figure 5.4 One coulomb of charge flowing each second is one amp.

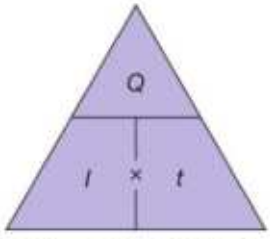
We can calculate the total charge that passes along a wire using the equation:

charge, Q (coulombs) = current, I (amps) × time, t (seconds)

$$Q = I \times t$$

HINT

If an examination question asks you to write out the equation for calculating charge, current or time, always give the actual equation such as $Q = I \times t$. You may not get the mark if you just draw the triangle.



▲ Figure 5.5 You can use the triangle method for rearranging equations like this.

EXAMPLE 1

a Calculate the charge flowing through a wire in 5 s if the current is 3 A.

$Q = I \times t$

$= 3\text{ A} \times 5\text{ s}$

$= 15\text{ C}$

b How many electrons flow through the wire in this time?

1 C of charge is carried by 6×10^{18} electrons

15 C of charge requires $15 \times 6 \times 10^{18}$ electrons = 90×10^{18} electrons

So 90 million, million, million electrons will flow along the wire in 5 s.

VOLTAGE

We often use cells or batteries to move charges around circuits. We can imagine them as being 'electron pumps'. They transfer energy to the charges. The amount of energy given to the charges by a cell or battery is measured in volts (V) and is usually indicated on the side of the battery or cell.

If we connect a 1.5 V cell into a circuit (Figure 5.6) and current flows, 1.5 J of energy is given to each coulomb of charge that passes through the cell.

If two 1.5 V cells are connected in series (Figure 5.7) so that they are pumping (pushing) in the same direction, each coulomb of charge will receive 3 J of energy.

The volt is a joule per coulomb.



▲ Figure 5.6 When one coulomb of charge passes through this cell it gains 1.5 J of energy.



▲ Figure 5.7 When one coulomb of charge passes through both these cells in turn it gains 3 J of energy.

KEY POINT

When several cells are connected together it is called a battery.

KEY POINT

Cells and batteries provide current which moves in one direction. This is known as direct current (d.c.).

As the charges flow around a circuit the energy they carry is transferred by the components they pass through. For example, when current passes through a bulb, energy is transferred to the surroundings as heat and light. When a current passes through the speaker of a radio, most of the energy is transferred as sound.

In the external part of a circuit (outside the cell or battery) the voltage across each component tells us how much energy it is transferring. If the voltage across a component is 1 V this means that the component is transferring 1 J of energy each time 1 C of charge passes through it.

We can describe the relationship between the energy transferred, charge and voltage using the equation:

energy transferred, E (joules) = charge, Q (coulombs) × voltage, V (volts)

$$E = Q \times V$$

EXAMPLE 2

The voltage across a light bulb is 12 V. Calculate the electrical energy transferred when 50 C of charge passes through it.

$E = Q \times V$
$= 50\ \text{C} \times 12\ \text{V}$
$= 600\ \text{J}$

Because $Q = I \times t$, we can also write this equation as $E = I \times t \times V$.

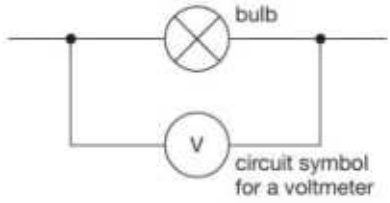
EXAMPLE 3

The voltage across a heater is 230 V. There is a current of 5 A through the heater for 5 mins. Calculate the total amount of energy transferred during this time.

$E = I \times t \times V$
$= 5\ \text{A} \times (5 \times 60)\ \text{s} \times 230\ \text{V}$
$= 345\,000\ \text{J}$ or 345 kJ

MEASURING VOLTAGES





▲ Figure 5.8 A voltmeter measures voltages across a component.

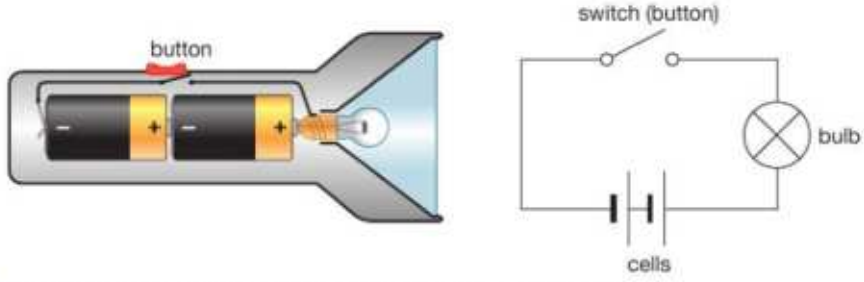
KEY POINT

A voltmeter has a very high resistance, so very little current flows through it.

We measure voltages using a voltmeter. This is connected across (in parallel with) the component we are investigating. A voltmeter connected across a cell or battery will measure the energy given to each coulomb of charge that passes through it. A voltmeter connected across a component will measure the electrical energy transferred when each coulomb of charge passes through it.

ELECTRICAL CIRCUITS

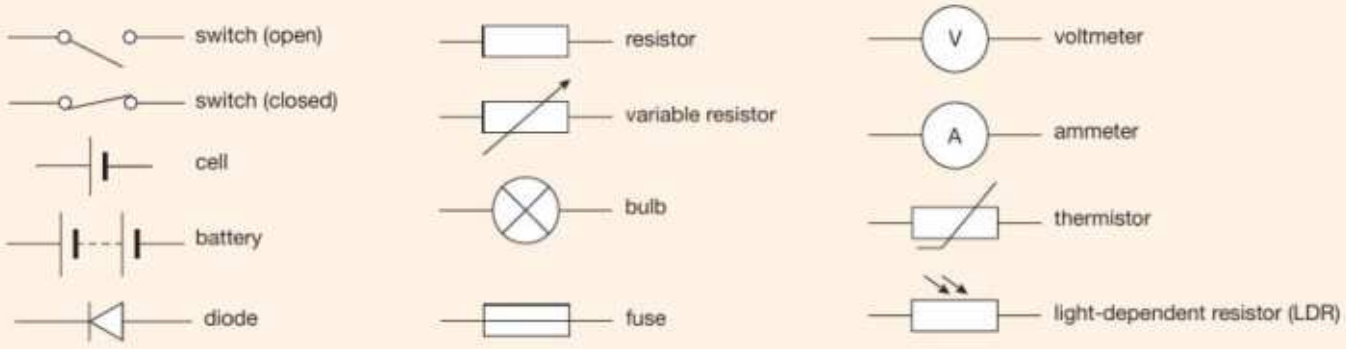
When the button on the torch shown in Figure 5.9 is pressed, the circuit is complete – that is, there are no gaps. Charges are able to flow around the circuit and the torch bulb glows. When the button is released the circuit becomes incomplete. Charges cease to flow and the bulb goes out.



▲ Figure 5.9 A torch contains a simple electrical circuit – a series circuit.

KEY POINT

Drawing diagrams of the actual components in a circuit is a very time-consuming and skilful task. It is much easier to use symbols for each of the components. Diagrams drawn in this way are called circuit diagrams. Figure 5.10 shows common circuit components and their symbols. You should know the common symbols but the less common ones will be given to you in the exam if you need them. Do not waste time memorising the less common ones.



▲ Figure 5.10 Circuit symbols



▲ Figure 5.11 Glowing LEDs indicate which circuits are working

IS IT ON?

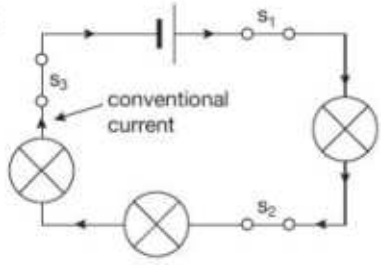
We sometimes put a small bulb or lamp in a circuit to show us if a circuit is 'turned on'. When there is a current in the circuit the bulb glows or shines. **Light emitting diodes (LEDs)** also glow when there is a current in a circuit but they require far less energy than bulbs. This is why many appliances such as TVs, DVD players and routers use small LEDs to show when the appliance is working or on standby.

SERIES AND PARALLEL CIRCUITS

There are two main types of electrical circuit. There are those circuits where there are no branches or junctions and there is only one path the current can follow. These simple 'single loop' circuits are called series circuits.

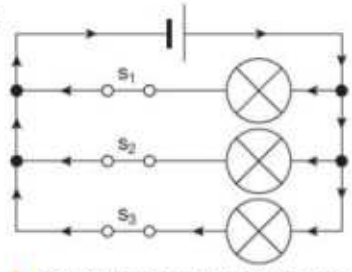
Circuits that have branches or junctions and more than one path that the current can follow are called parallel circuits.

a



▲ Figure 5.12a A typical series circuit. Opening any one of these switches will turn all three bulbs off.

b



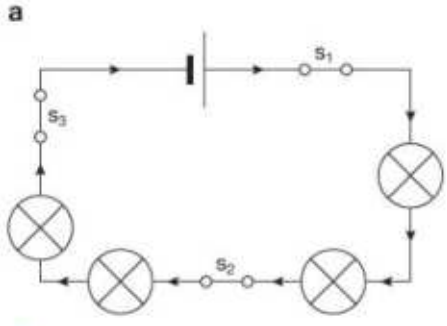
▲ Figure 5.12b A typical parallel circuit. Opening any one of these switches will turn off just the bulb in that part of the circuit.

Series circuits and parallel circuits behave differently. This makes them useful in different situations.

In a series circuit containing bulbs:

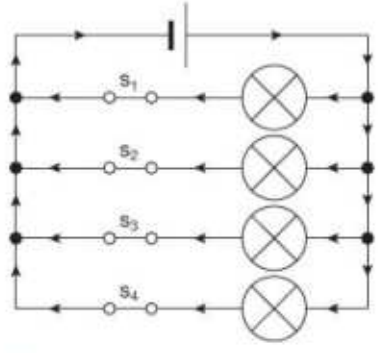
- One switch placed anywhere in the circuit can turn all the bulbs on and off.
- If any one of the bulbs breaks, it causes a gap in the circuit and all of the other bulbs will 'stop working'.
- The energy supplied by the cell is 'shared' between all the bulbs, so the more bulbs you add to a series circuit the less bright they all become.

a



▲ Figure 5.13a Adding an extra bulb in series will result in the bulbs shining less brightly.

b



▲ Figure 5.13b Adding an extra bulb in parallel does not affect the brightness of the other bulbs.



▲ Figure 5.14 Decorative lights are usually wired in series.

In a parallel circuit containing bulbs:

- Switches can be placed in different parts of the circuit to switch each bulb on and off individually, or all together.
- If one bulb breaks, only the bulbs on the same branch of the circuit will be affected.
- Each branch of the circuit receives the same voltage, so if more bulbs are added to a circuit in parallel they all keep the same brightness.

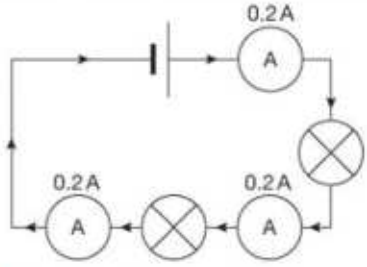
Decorative lights are often wired in series. Each bulb only needs a low voltage, so even when the voltage from the mains supply is 'shared' out between them each bulb still gets enough energy to produce light. Unfortunately, if the filament in one of the bulbs breaks then all the other bulbs will go out.

The lights in your home are wired in parallel. We know this because lights can be switched on and off separately, and the brightness of each light does not change when other lights are on or off. Also, if a bulb breaks or is removed, you can still use the other lights.

CURRENT IN A SERIES CIRCUIT

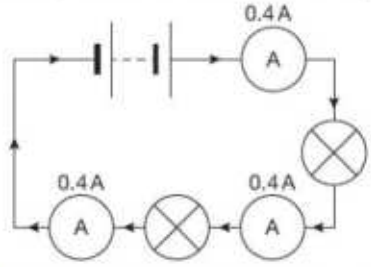
In a series circuit the current is the same in all parts; current is not used up.

a



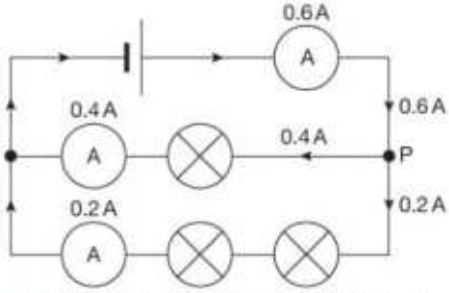
▲ Figure 5.15a In a series circuit the current does not vary.

b



▲ Figure 5.15b The addition of a second cell doubles the voltage applied to the circuit so the current will also double.

The size of the current in a series circuit depends on the voltage supplied to it, and the number and type of the other components in the circuit. If a second identical cell is added in series the voltage will double and so the current will also double.



▲ Figure 5.16 There are different currents in the different parts of a parallel circuit.

CURRENT IN A PARALLEL CIRCUIT

In a parallel circuit the currents will not be the same in different parts of the circuit. The types of components in each of the different parts will affect the currents.

In a parallel circuit the number of electrons that flow into a junction each second must be equal to the number that leave each second. This means that the currents entering a junction must always be equal to those that leave. For example, in Figure 5.16 the current that enters junction P is 0.6 A. The current that leaves is 0.4 A + 0.2 A = 0.6 A.

CHAPTER QUESTIONS

More questions on electrical circuits can be found at the end of Unit 2 on page 554.

SKILLS CRITICAL THINKING

1 Current is a flow of charge.

a What are the charge carriers in metals?

b Explain why charges are able to flow through metals but not through a plastic.

SKILLS PROBLEM SOLVING

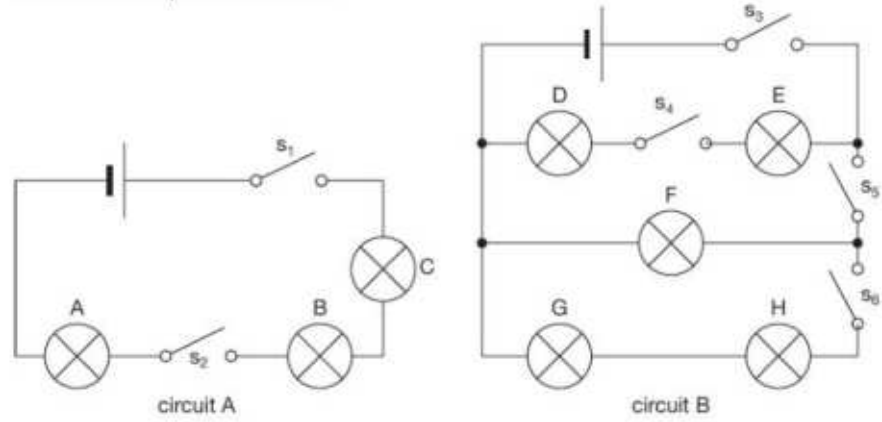
c If the current in a heater is 3 A, calculate the charge that flows through it in:
i 1 s
ii 10 min
iii 1 hour.

SKILLS CRITICAL THINKING

2 a Explain the differences between:
i a complete circuit and an incomplete circuit
ii a series circuit and a parallel circuit.

SKILLS ANALYSIS

b Look carefully at the circuits shown below. Assuming that all switches are initially closed, decide which of the bulbs go out when each of the switches is opened in turn.



c In circuit A, which bulb(s) glow the brightest when all the switches in the circuit are closed?

SKILLS CRITICAL THINKING

d Explain your answer to part c.

SKILLS INTERPRETATION

3 The voltage between two points in a circuit is measured using a voltmeter.

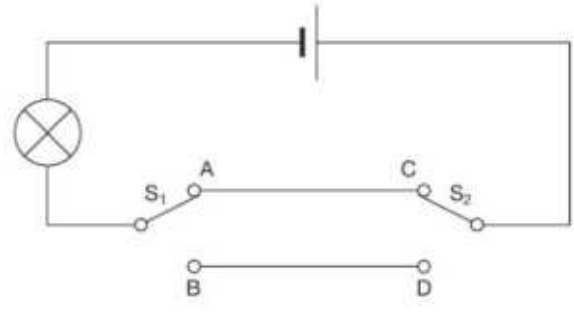
a Draw a circuit diagram to show how a voltmeter should be connected to measure:
i the voltage across a bulb ii the voltage of a cell.

SKILLS CRITICAL THINKING

b Explain in your own words the phrase 'a cell has a voltage of 1.5 V'.

SKILLS REASONING

4 The diagram below shows a circuit containing two 2-way switches.



a Explain in your own words what happens when each of the switches is moved to a new position.

b Suggest one important application of this circuit in the home.

5 Should the lights for the main street in a town be wired in series or in parallel? Explain your answer.

6 Why would it not be a good idea to connect all the different parts of an electric cooker (oven, grill, heating plates) in series?

6 ELECTRICAL RESISTANCE

In this chapter you will learn what resistance is and how it can be useful in electrical appliances. You will learn what factors affect resistance and how to work out the resistance of a component by measuring the current in it and the voltage across it (Ohm's law). You will also read about some special resistors, and their uses.

It is likely that almost every day of your life you will make some adjustments to at least one electrical appliance. You may turn up the volume of your radio or change the brightness of a light. In each of these examples your adjustments are changing the currents and the voltages in the circuits of your appliance. You are doing this by altering the resistance of the circuits. This chapter will help you understand the meaning and importance of resistance and how we make use of it.



▲ Figure 6.1 Turning this dial alters the resistance in the circuit which changes the volume of the sound.

LEARNING OBJECTIVES

- Understand how the current in a series circuit depends on the applied voltage and the number and nature of other components
- Describe how current varies with voltage in wires, resistors, metal filament lamps and diodes, and how to investigate this experimentally
- Describe the qualitative effect of changing resistance on the current in a circuit
- Describe the qualitative variation of resistance of light-dependent resistors (LDRs) with illumination and thermistors with temperature
- Calculate the currents, voltages and resistances of two resistive components connected in a series circuit

RESISTANCE

REMINDER

We normally assume that connecting wires have zero resistance.

All components in a circuit offer some resistance to the flow of charge. Some (for example, connecting wires) allow charges to pass through very easily losing very little of their energy. We describe connecting wires as having very low resistance. The flow of charge through some components is not so easy and a large amount of energy may be used to move the charges through them. This energy is transferred, usually as heat. Components like these are said to have a high resistance.

We measure the resistance (R) of a component by comparing the size of the current (I) in that component and the voltage (V) applied across its ends. Voltage, current and resistance are related as follows:

voltage, V (volts) = current, I (amps) × resistance, R (ohms)

$$V = I \times R$$

We measure resistance in units called ohms (Ω).

HINT

If an examination question asks you to write out the equation for calculating resistance, current or voltage, always give the actual equation such as $V = I \times R$. You may not get the mark if you just draw the triangle.

EXAMPLE 1

When a voltage of 12 V is applied across a doorbell there is a current of 0.1 A. Calculate the resistance of the doorbell.

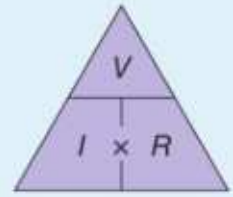
$$V = I \times R$$

Rearrange the equation.

$$R = \frac{V}{I}$$

$$= \frac{12\,\text{V}}{0.1\,\text{A}}$$

$$= 120\,\Omega$$

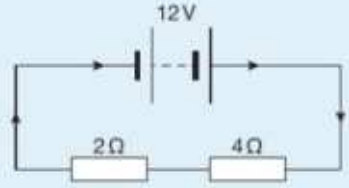


▲ Figure 6.2 You can use the triangle method for rearranging equations like $V = I \times R$.

If there are two or more resistors connected in series in a circuit, their total resistance is found by simply adding the individual resistances together. (This is not true for parallel circuits. You do not need to know how to do this.)

EXAMPLE 2

The circuit on the right contains a 12 V battery and two resistors connected in series.



▲ Figure 6.3 Two resistor series circuit

Calculate

a the current in each of the resistors

b the voltage across each resistor.

a The total resistance the current must pass through is $2\,\Omega + 4\,\Omega = 6\,\Omega$

The current in the circuit (I) is therefore:

$$I = \frac{V}{R}$$

$$= \frac{12\,V}{6\,\Omega}$$

$$= 2\,\text{A}$$

The current in a series circuit is the same everywhere. So the current in both resistors is 2 A.

b Using $V = I \times R$

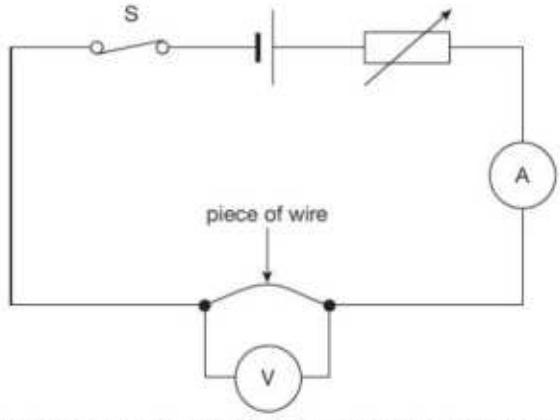
for the 2 Ω resistor: $V = 2\,\text{A} \times 2\,\Omega = 4\,\text{V}$

for the 4 Ω resistor: $V = 2\,\text{A} \times 4\,\Omega = 8\,\text{V}$

EXPERIMENT TO INVESTIGATE HOW CURRENT VARIES WITH VOLTAGE FOR DIFFERENT COMPONENTS

Safety note: The resistance wire in the circuit may get hot enough to burn skin if the current/voltage is increased too much.

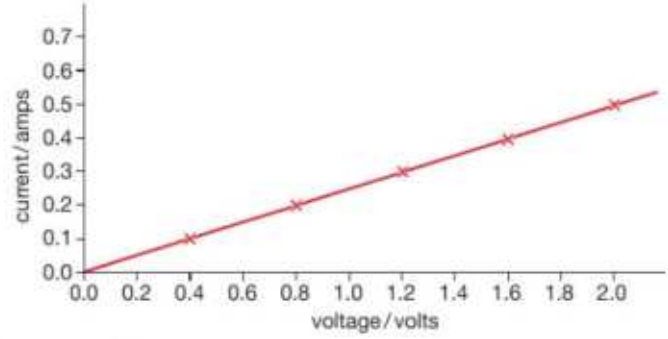
1. Set up the circuit shown in Figure 6.4.
2. Turn the variable resistor to its maximum value.
3. Close the switch and take the readings from the ammeter and the voltmeter.
4. Alter the value of the variable resistor again and take a new pair of readings from the meters.
5. Repeat the whole process at least six times.
6. Place the results in a table (see the table below) and draw a graph of current (*I*) against voltage (V).



▲ Figure 6.4 This circuit can be used to investigate the relationship between current and voltage.

Current / amps	Voltage / volts
0.0	0.0
0.1	0.4
0.2	0.8
0.3	1.2
0.4	1.6
0.5	2.0

▲ Table 6.1 Typical results table

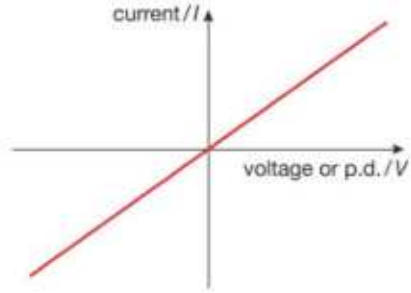


▲ Figure 6.5 Graph of results

The graph in Figure 6.5 is a straight line graph passing through the origin. The slope of the graph tells us about the resistance of the wire. The steeper the slope the smaller the resistance of the wire.

If we repeat this experiment for other components, such as a resistor, a filament bulb and a diode, the shapes of the graphs we obtain are often very different to that shown in Figure 6.5. By looking very carefully at these shapes we can see how they behave.

CURRENT/VOLTAGE GRAPH FOR A WIRE OR A RESISTOR



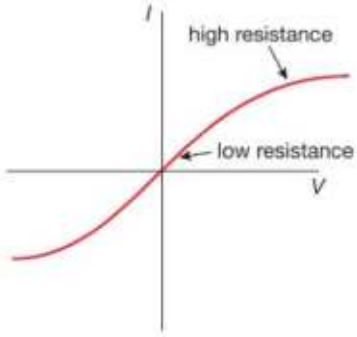
▲ Figure 6.6

The graph is a straight line. It has a constant slope. So the resistance of this component does not change.

CURRENT/VOLTAGE GRAPH FOR A FILAMENT BULB

HINT

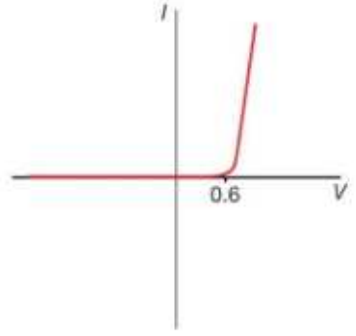
The flatter the slope the higher the resistance.



▲ Figure 6.7

This graph is not a straight line. The resistance of the bulb changes. At higher currents and voltages the slope of the graph shows us that the resistance of the filament bulb increases – that is, as the temperature of the filament increases the current decreases.

CURRENT/VOLTAGE GRAPH FOR A DIODE



▲ Figure 6.8

This strangely shaped graph shows that diodes have a high resistance when the current is in one direction and a low resistance when it is in the opposite direction (see page 551).

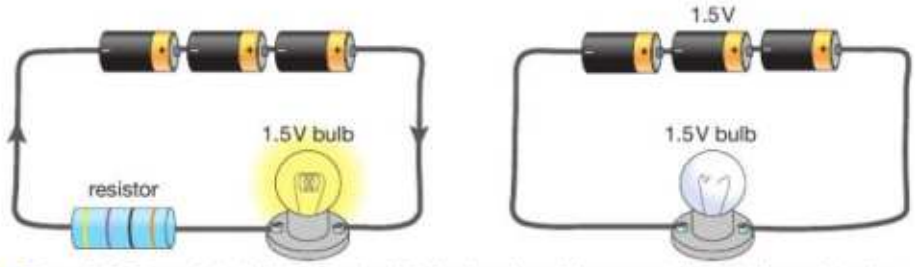
USING RESISTANCE

FIXED RESISTORS

In many circuits you will find components similar to those shown in Figure 6.9. They are called fixed resistors. They are included in circuits in order to control the sizes of currents and voltages. The resistor in the circuit in Figure 6.10 is included so that both the current in the bulb and the voltage applied across it are correct. Without the resistor the voltage across the bulb may cause too large a current and the bulb may 'blow' or break.



▲ Figure 6.9 A selection of resistors



▲ Figure 6.10 The resistor in the first circuit limits the size of the current. Without the resistor the current in the second circuit is too high and the bulb breaks.

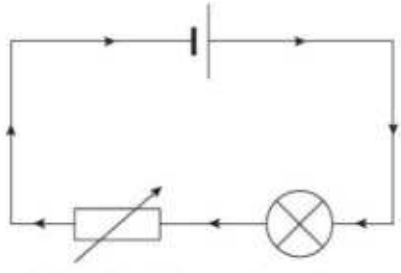
VARIABLE RESISTORS

Figure 6.11 shows examples of a different kind of resistor. They are called variable resistors as it is possible to alter their resistance. If you alter the volume of your radio using a knob you are using a variable resistor to do this.



▲ Figure 6.11 Variable resistors and their symbol

In the circuit in Figure 6.12 a variable resistor is being used to control the size of the current in a bulb. If the resistance is decreased there will be a larger current and the bulb shines more brightly. If the resistance is increased the current will be smaller and the bulb will glow less brightly or not at all. The variable resistor is behaving in this circuit as a **dimmer switch**. In circuits containing electric motors, variable resistors can be used to control the speed of the motor.

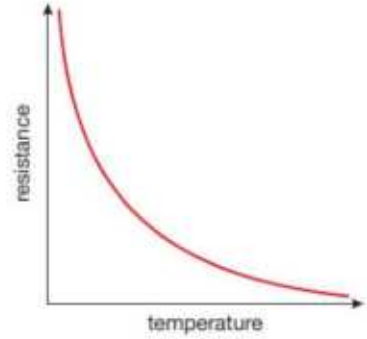


▲ Figure 6.12 Circuit with a variable resistor being used as a dimmer switch

SPECIAL RESISTORS

THERMISTORS

A **thermistor** is a resistor whose resistance changes quite a lot even with small changes in temperature.



▲ Figure 6.13 A graph showing a thermistor's decreasing resistance with increasing temperature

KEY POINT

Some thermistors increase their resistance when the temperature increases. However, for your International GCSE Physics exam you only need to know about thermistors whose resistance decreases with increasing temperature.

Thermistors are used in temperature-sensitive circuits in devices such as fire alarms. They are also used in devices where it is important to make sure there is no change in temperature, for example, in freezers and computers.

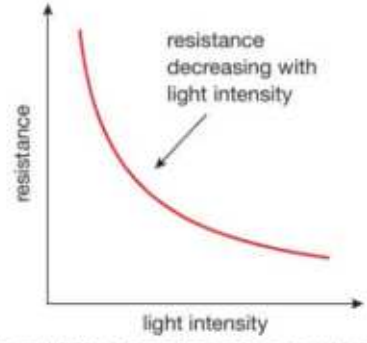




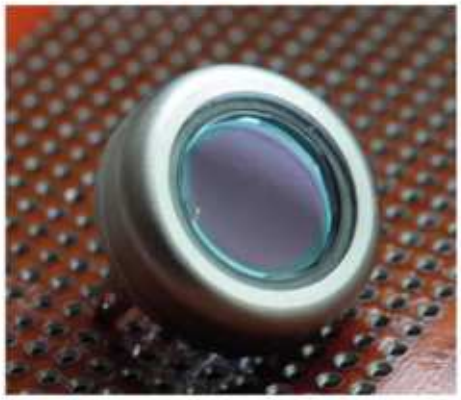
▲ Figure 6.14 Two examples of thermistors and their symbol – the resistance of a thermistor changes a lot as the temperature changes.

LIGHT-DEPENDENT RESISTORS (LDRs)

A light-dependent resistor (LDR) has a resistance that changes when light is shone on it. In the dark its resistance is high but when light is shone on it its resistance decreases.



▲ Figure 6.15 A graph showing an LDR's decreasing resistance with increasing light intensity



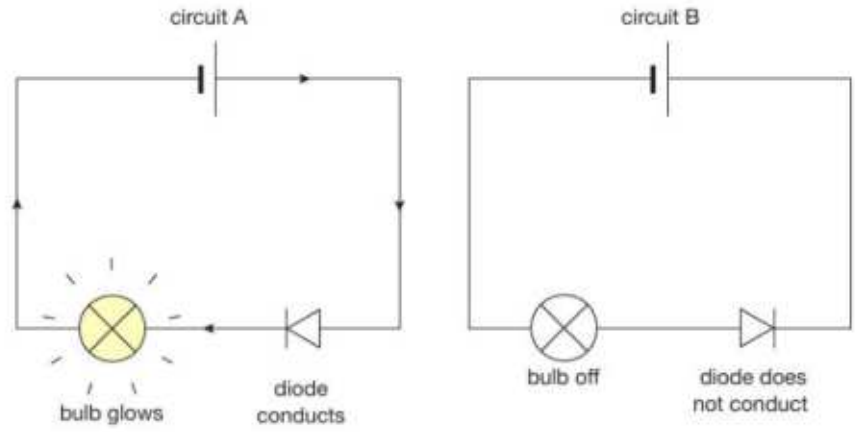
▲ Figure 6.16 Light-dependent resistor

LDRs are often used in light-sensitive circuits in devices such as photographic-exposure equipment, automatic lighting controls and burglar alarms.

DIODES

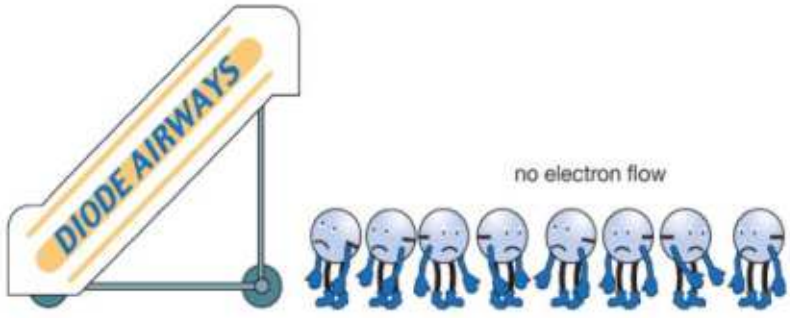
Diodes are very special resistors that allow charges to flow through them easily but only in one direction.

When a diode is connected as shown in circuit A in Figure 6.17, the diode offers little resistance to the charges flowing through it. But if the diode is connected the opposite way round, the diode has a very high resistance and the rate at which the charges can flow through the diode is much less – that is, the current is very small. Diodes are often used in circuits where it is important that electrons flow only in one direction. For example, they are used in **rectifier circuits** that convert alternating current into direct current. Some diodes glow when charges flow through them. They are called light emitting diodes (LEDs).



▲ Figure 6.17 Diodes will only let charges flow one way.





▲ Figure 6.18 Diodes are like aeroplane steps – from the ground, you can only climb them in one direction. In a diode the charge can only flow in one direction.

KEY POINT

You can imagine a diode as behaving like a set of aeroplane steps which the charges have to climb over. If the charges are moving towards the correct side of the steps they can 'flow through it'. If, however, they try to move the opposite way there are no steps for them to climb so the flow in this direction is almost zero.

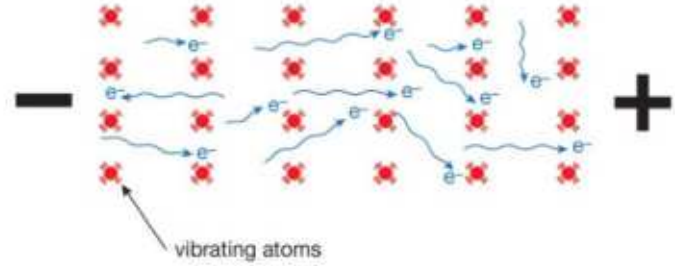
LOOKING AHEAD – OHM'S LAW AND TEMPERATURE

The relationship between the voltage across a component and its current is described by Ohm's law, which states:

> *The current in a conductor is directly proportional to the potential difference across its ends, provided its temperature remains constant.*

So the resistance of a wire can be found by measuring the voltage (V) across it and the current (I) in it when this voltage is applied to the wire and then calculating a value for the **ratio** $\frac{V}{I}$ (see page 545). But the law also states that the temperature of the wire must be constant. This is because if the temperature of the wire changes, its resistance also changes.

This happens because at higher temperatures the atoms in the wire **vibrate** more vigorously, making it more difficult for the electrons to flow.



▲ Figure 6.19 At higher temperatures the increased vibration of the atoms makes it more difficult for charges to flow.

If a wire or conductor is cooled the vibration of its atoms decreases and so its resistance decreases. At very low temperatures, close to absolute zero (–273 °C), these vibrations stop and the conductor offers no resistance to the flow of charge. This event is called superconductivity and could be extremely useful. For example, when electricity flows through a superconductor there is no loss of energy. This means that by using superconductivity we could transmit electrical energy from power stations without losses. Scientists around the world are now searching for materials that are superconductors at temperatures well above absolute zero.



▲ Figure 6.20 Maglev trains use superconducting magnets to help them hover above the tracks.

CHAPTER QUESTIONS

More questions on electrical resistance can be found at the end of Unit 2 on page 554.

SKILLS CRITICAL THINKING

1 a Describe how the current in a wire changes as the voltage across the wire increases.

SKILLS INTERPRETATION

b Draw a diagram of the circuit you would use to confirm your answer to part a.

SKILLS DECISION MAKING

c Describe how you would use the apparatus and what readings you would take.

SKILLS INTERPRETATION

d Draw an *I*–*V* graph for

i a piece of wire at room temperature
ii a filament bulb
iii a diode.

Explain the main features of each of these graphs.

SKILLS PROBLEM SOLVING

2 a There is a current of 5 A when a voltage of 20 V is applied across a resistor. Calculate the resistance of the resistor.

b Calculate the current when a voltage of 12 V is applied across a piece of wire of resistance 50 Ω.

c Calculate the voltage that must be applied across a wire of resistance 10 Ω if the current is to be 3 A.

SKILLS INTERPRETATION

3 a Describe how the resistance of

i a thermistor changes as its temperature changes
ii a light-dependent resistor changes as an increasingly bright light is shone on it.
iii Draw graphs to illustrate these changes.

SKILLS CRITICAL THINKING

b Name one practical application for each of these resistors.

HINT

Remember when doing calculations like these to show all your working out and include units with your answer.

UNIT QUESTIONS

SKILLS CRITICAL THINKING 4 5 6 **1**

a Which of the following is not used to protect us from the possibility of receiving an electric shock?

A double insulation
B live wire
C earth wire
D circuit breaker

(1)

6

b Which of the following is true for a **negatively charged** object?

A It will attract another negatively charged object.
B It has too few electrons.
C It has too many neutrons.
D It has gained extra electrons.

(1)

4 5

c Which of the following is true for all parallel circuits?

A Parts of the circuit can be turned off while other parts remain on.
B The current is the same in all parts of the circuit.
C There is only one path for the current to follow.
D There are no junctions or branches.

(1)

SKILLS PROBLEM SOLVING 7

d When a voltage of 6 V is applied across a resistor there is a current of 0.1 A. The value of the resistor is

A 6 Ω
B 60 Ω
C 16.6 Ω
D 0.6 Ω

(1)

(Total 4 marks)

SKILLS CRITICAL THINKING 6 **2**

Copy and complete the following passage about electricity, filling in the spaces.

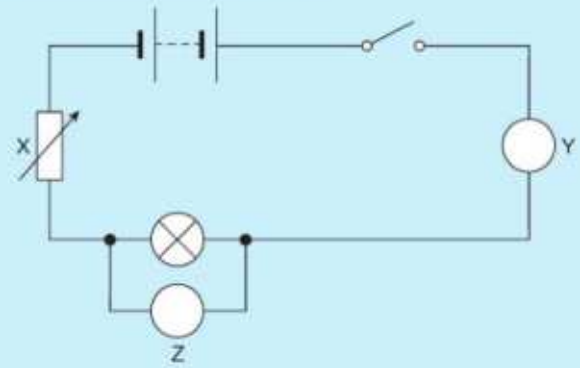
An electric current is a flow of _____. A current of 1 amp is 1 _____ of charge flowing each second. The voltage is the _____ transferred per coulomb of charge.

The current in a component depends on the voltage and the _____; the higher the resistance, the _____ the current.

(Total 5 marks)

SKILLS ANALYSIS

3 Asma set up the circuit shown below to investigate how the resistance of a bulb changes as the current in it changes.

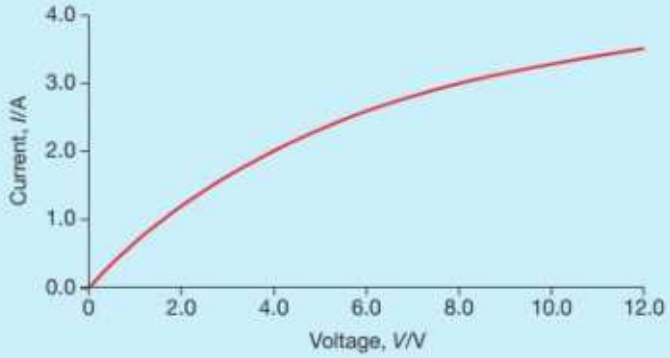


a What are the names of the instruments labelled Y and Z? **(2)**

b What is the name of the component labelled X? **(1)**

c What is the purpose of X in this circuit? **(1)**

Asma takes a series of readings. She measures the voltage across the bulb and the current in it. She then plots the graph shown below.



d What is the current in the bulb when a voltage of 6 V is applied across it? **(1)**

e What voltage is applied across the bulb when there is a current of 2 A? **(1)**

SKILLS PROBLEM SOLVING

f Calculate the resistance of the bulb when there is a current of 2 A. **(2)**

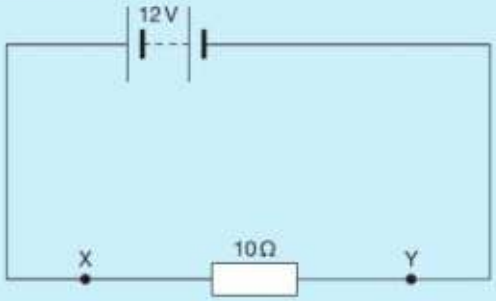
SKILLS REASONING

g What happens to the resistance of the bulb as the current increases? **(1)**

(Total 9 marks)

SKILLS PROBLEM SOLVING

4 A simple series circuit containing a 12 V battery and a 10 Ω resistor was constructed as shown below.



8th

a Calculate the current between points X and Y. **(2)**

7th

b Calculate the total charge that flows between X and Y in 5 s. **(2)**

c Calculate the energy transferred in the resistor in 1 minute. **(2)**

(Total 6 marks)

5 An electric kettle is rated at 2 kW when connected to a 230 V electrical supply.

a Calculate the current when the kettle is turned on. **(3)**

5th

b What value fuse should be included in the circuit of the kettle? (Assume that the fuses available are 3 A, 5 A and 13 A.) **(1)**

SKILLS CRITICAL THINKING 6th

c Modern kettles often have double insulation. Explain what this means and how it provides extra safety for the user. **(2)**

SKILLS PROBLEM SOLVING 8th

d Calculate the resistance of the heating element of the kettle. **(3)**

(Total 9 marks)

SKILLS CRITICAL THINKING 6th

6 **a** Explain in detail how insulating materials can be charged by friction. **(4)**

SKILLS REASONING

b When an aircraft lands it is important that it is earthed before it is refuelled.

7th

i Explain why the aircraft should be earthed. **(3)**

6th

ii Suggest one way in which the aircraft could be earthed. **(1)**

7th

c Explain why electrostatic painting of objects, such as bicycle frames, makes good economic sense. **(3)**

SKILLS CRITICAL THINKING 6th

d Describe briefly how an inkjet printer makes use of some of the properties of static electricity. **(3)**

(Total 14 marks)

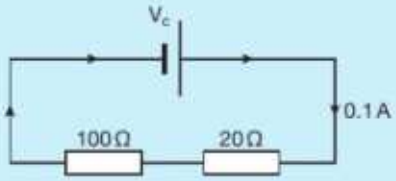
7 a Describe four uses of the heating effect of electricity in the home. **(4)**

b Explain why a double-insulated hairdryer does not need an earth wire in its cable. **(2)**

(Total 6 marks)

SKILLS PROBLEM SOLVING

8 Calculate



a the voltage across the 20 Ω resistor **(2)**

b the voltage across the 100 Ω resistor **(2)**

c the voltage of the cell (V_c). **(1)**

(Total 5 marks)

PROPERTIES OF WAVES 559 | THE ELECTROMAGNET SPECTRUM 568 | LIGHT AND SOUND WAVES 575

PHYSICS UNIT 3 WAVES

There are many different types of waves. They affect all of our lives. Sometimes they are useful and can be a tremendous benefit to the way we live. Sometimes they can be dangerous and pose a real risk to life. It is therefore very important that we understand the main features and properties of waves.



7 PROPERTIES OF WAVES

Talking to someone using a mobile phone is something most of us do several times a day. The technology that had to be developed for this to happen was based on a thorough understanding of the properties of waves.

In this chapter you will learn about different types of waves and their properties (characteristics).



▲ Figure 7.1 Using microwaves to communicate

LEARNING OBJECTIVES

- Explain the difference between longitudinal and transverse waves
- Know the definitions of amplitude, wavefront, frequency, wavelength and period of a wave
- Know that waves transfer energy and information without transferring matter
- Know and use the relationship between the speed, frequency and wavelength of a wave:

  wave speed = frequency × wavelength

  $v = f \times \lambda$
- Use the relationship between frequency and time period:

  $$\text{frequency} = \frac{1}{\text{time period}}$$

  $$f = \frac{1}{T}$$
- Use the above relationships in different contexts including sound waves and electromagnetic waves
- Explain that all waves can be reflected and refracted
- Explain why there is a change in the observed frequency and wavelength of a wave when its source is moving relative to an observer, and that this is known as the Doppler effect

UNITS

In this unit, you will need to use degrees (°) as the unit of angle, hertz (Hz) as the unit of frequency, metre (m) as the unit of length, metre per second (m/s) as the unit of speed and second (s) as the unit of time.

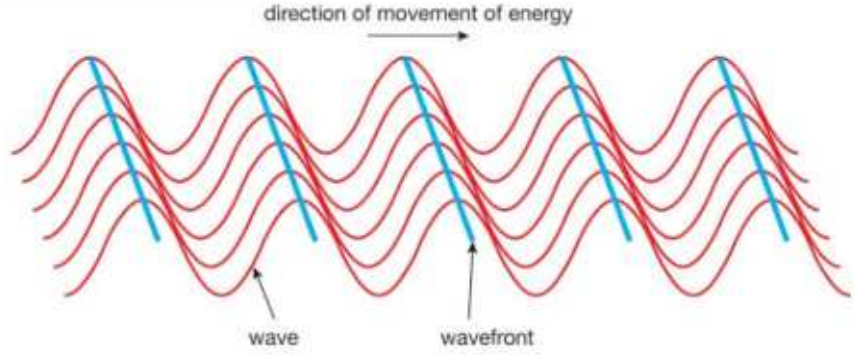
WHAT ARE WAVES?

Waves are a way of transferring energy from place to place. As we can see in Figure 7.1 we often use them to transfer information. All these transfers take place with no matter being transferred.



▲ Figure 7.2 Waves are produced if we drop a stone into a pond. The circular wavefronts spread out from the point of impact, carrying energy in all directions, but the water in the pond does not move from the centre to the edges.

WHAT ARE WAVEFRONTS?

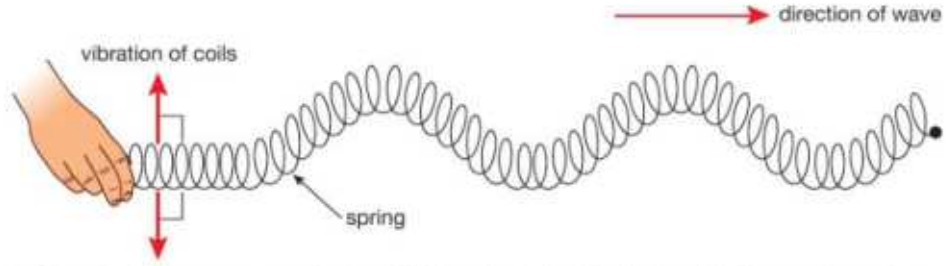


▲ Figure 7.3 Wavefronts are created by overlapping lots of different waves. A wavefront is a line where all the vibrations are in phase and the same distance from the source.

TRANSVERSE WAVES

Waves can be produced in ropes and springs. If you move one end of a spring from side to side you will see waves travelling through it. The energy carried by these waves moves along the spring from one end to the other, but if you look closely you can see that the coils of the spring are vibrating (shaking) across the direction in which the energy is moving. This is an example of a **transverse wave**.

A transverse wave is one that vibrates, or oscillates, at right angles to the direction in which the energy or wave is moving. Examples of transverse waves include light waves and waves travelling on the surface of water.



▲ Figure 7.4 A transverse wave vibrates at right angles to the direction in which the wave is moving.

LONGITUDINAL WAVES

If you push and pull the end of a spring in a direction parallel to its axis, you can again see energy travelling along it. This time however the coils of the spring are vibrating in directions that are along its length. This is an example of a **longitudinal wave**.

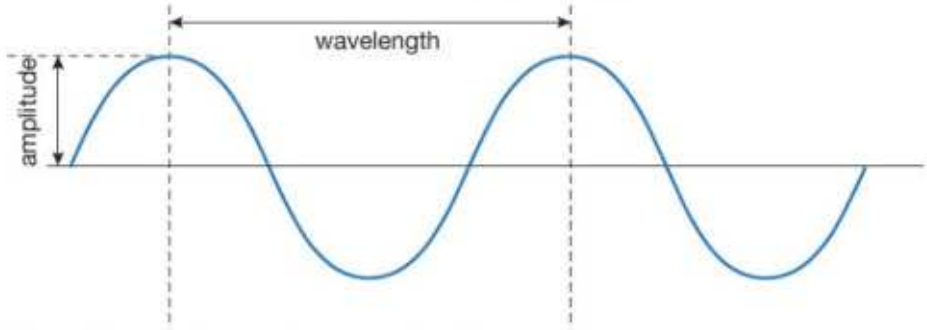


▲ Figure 7.5 A longitudinal wave vibrates along the direction in which the wave is travelling.

A longitudinal wave is one in which the vibrations, or oscillations, are along the direction in which the energy or wave is moving. Examples of longitudinal waves include sound waves.

DESCRIBING WAVES

When a wave moves through a substance, its particles will move from their equilibrium (resting position). The maximum movement of particles from their resting or equilibrium position is called its **amplitude** (A).



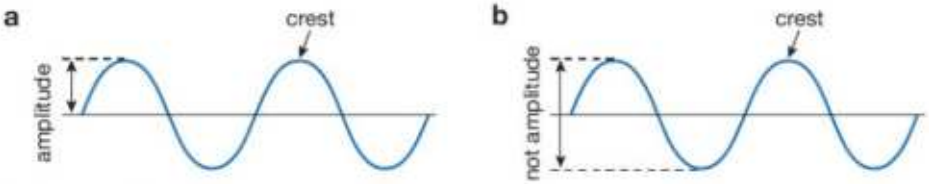
▲ Figure 7.6 A wave has amplitude and wavelength.

The distance between a particular point on a wave and the same point on the next wave (for example, from crest to crest) is called the **wavelength** (λ).

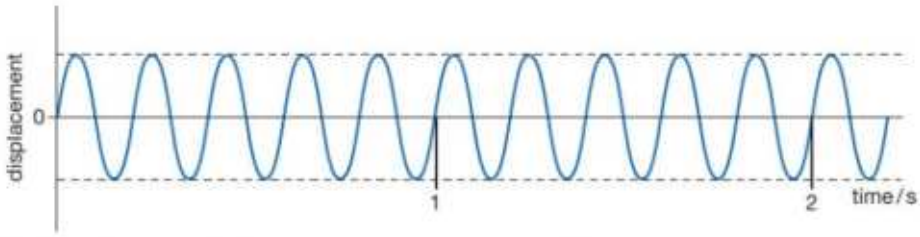
If the source that is creating a wave vibrates quickly it will produce a large number of waves each second. If it vibrates more slowly it will produce fewer waves each second. The number of waves produced each second by a source, or the number passing a particular point each second, is called the frequency of the wave (f). Frequency is measured in hertz (Hz). A wave source that produces five complete waves each second has a frequency of 5 Hz.

KEY POINT

λ is the Greek letter lambda and is the usual symbol for wavelength.



▲ Figure 7.7 The amplitude of a wave is as shown in **a**, and not as in **b**.



▲ Figure 7.8 This graph shows a wave with a frequency of 5 Hz.

The time it takes for a source to produce one wave is called the **time period** of the wave (T). It is related to the frequency (f) of a wave by the equation:

$$\text{frequency, } f \text{ (Hz)} = \frac{1}{\text{time period, } T \text{ (s)}}$$

$$f = \frac{1}{T}$$

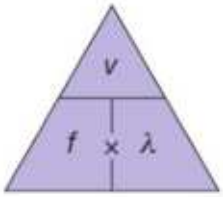
This equation can also be written as

$$T = \frac{1}{f}$$

EXAMPLE 1

Calculate the period of a wave with a frequency of 200 Hz.

$$T = \frac{1}{f}$$
$$= \frac{1}{200\ \text{Hz}}$$
$$= 0.005 \text{ or } 5\ \text{ms}\ (1000\ \text{ms} = 1\ \text{s})$$



▲ Figure 7.9 You can use the triangle method for rearranging equations like $v = f \times \lambda$.

HINT

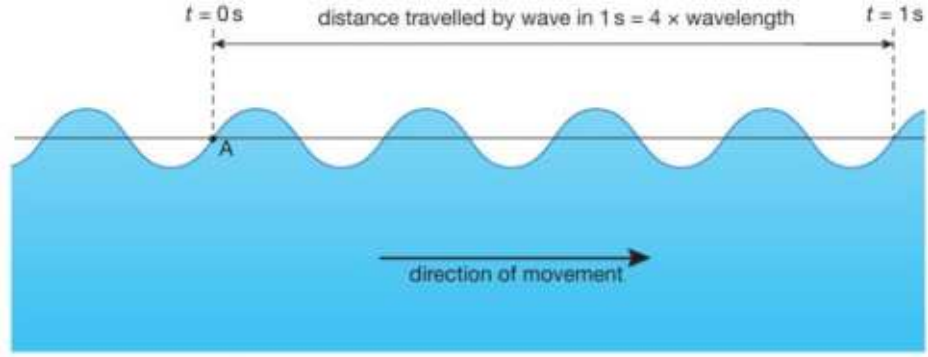
If an examination question asks you to write out the equation for calculating wave speed, wavelength or frequency, always give the actual equation such as $v = f \times \lambda$. You may not be awarded a mark if you just draw the triangle.

THE WAVE EQUATION

There is a relationship between the wavelength (λ), the frequency (f) and the wave speed (v) that is true for all waves:

wave speed, v (m/s) = frequency, f (Hz) × wavelength, λ (m)

$$v = f \times \lambda$$



▲ Figure 7.10 A wave with a frequency of 4 Hz

Imagine that you have created water waves with a frequency of 4 Hz. This means that four waves will pass a particular point each second. If the wavelength of the waves is 3 m, then the waves travel 12 m each second. The speed of the waves is therefore 12 m/s.

$$v = f \times \lambda$$
$$= 4\ \text{Hz} \times 3\ \text{m}$$
$$= 12\ \text{m/s}$$

EXAMPLE 2

A **tuning fork** creates sound waves with a frequency of 170 Hz. If the speed of sound in air is 340 m/s, calculate the wavelength of the sound waves.

$$v = f \times \lambda$$

So $$\lambda = \frac{v}{f}$$
$$= \frac{340\ \text{m/s}}{170\ \text{Hz}}$$
$$= 2\ \text{m}$$

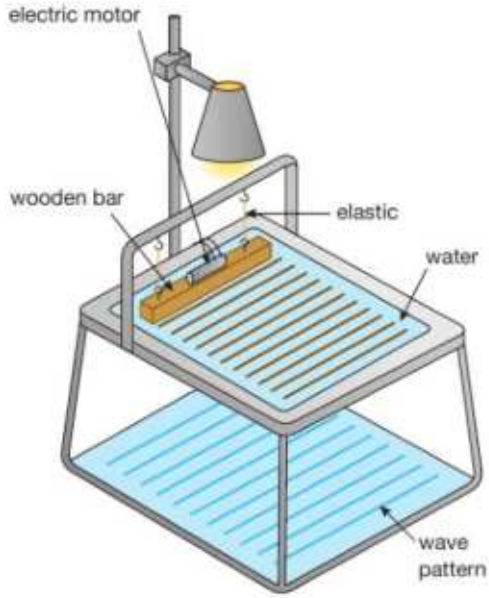


▲ Figure 7.11 A tuning fork

THE RIPPLE TANK

We can study the behaviour of water waves using a ripple tank.

When the motor is turned on, the wooden bar vibrates creating a series of ripples or wavefronts on the surface of the water. A light placed above the tank creates patterns of the water waves on the floor. By observing the patterns we can see how the water waves are behaving.

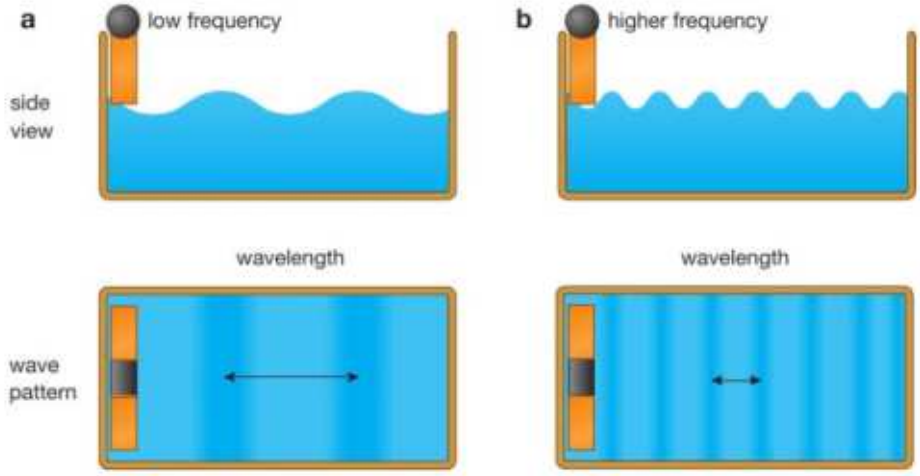


▲ Figure 7.12 The light shines through the water and we can see the patterns of the waves.

WAVELENGTH AND FREQUENCY

The motor can be adjusted to produce a small number of waves each second. The frequency of the waves is small and the pattern shows that the waves have a long wavelength.

At higher frequencies, the water waves have shorter wavelengths. The speed of the waves does not change.



▲ Figure 7.13 When the frequency of the waves is low, the wavelength is long. When the frequency is higher, the wavelength is shorter.

REFLECTION

All waves can be reflected. If they hit a straight or flat barrier, the angle at which they leave the barrier surface is equal to the angle at which they meet the surface – that is, the waves are reflected from the barrier at the same angle as they strike it. This is described by the 'Law of Reflection' which states that:

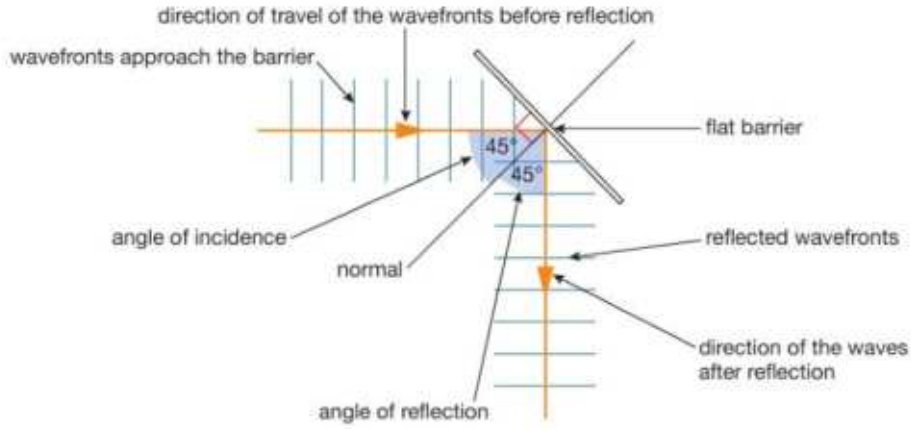
*The **angle of incidence** is equal to the **angle of reflection**.*

KEY POINT

A normal is a line drawn at right angles to a surface.

The angle of incidence is the angle between the direction of the waves as they approach the barrier and the normal.

The angle of reflection is the angle between the direction of the waves after striking the barrier and the normal.

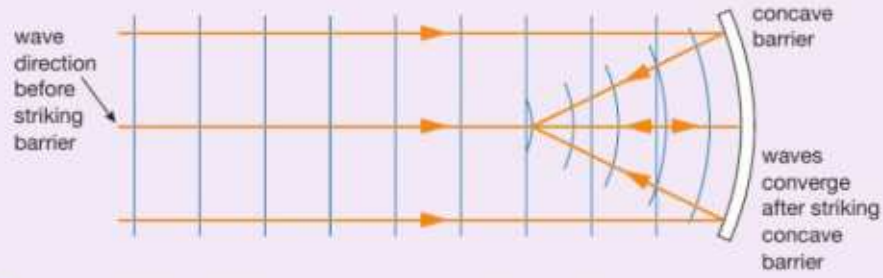


▲ Figure 7.14 Waves striking a flat barrier are reflected. The angle at which they strike the barrier is the same as the angle at which they are reflected.

EXTENSION WORK

Although you will not be asked this in your exam, it is interesting to see how waves are reflected from curved surfaces.

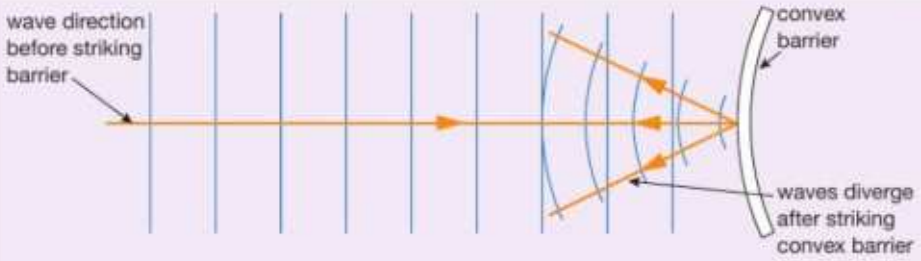
When the waves strike a concave barrier, they are made to converge (come together).



▲ Figure 7.15 Waves striking a concave barrier are reflected and converge.



▲ Figure 7.16 Radio telescopes have concave reflecting dishes so that the signals from space reflect and converge onto a detector that is placed in front of the dish.



▲ Figure 7.17 Waves striking a convex barrier are reflected backwards and spread out.

When waves are reflected by a surface that is curved outwards (convex), they diverge (spread out).



▲ Figure 7.18 The light waves reflected from this concave make-up mirror create a magnified image.



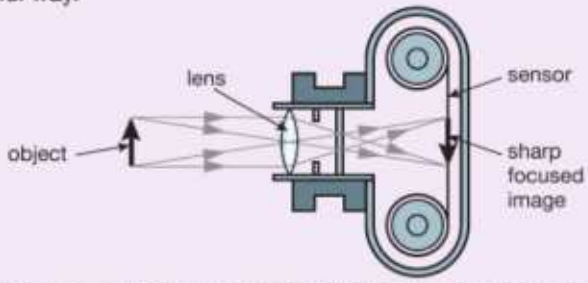
▲ Figure 7.19 **a** The pencil seems to bend at the air/water boundary. **b** Why the pencil appears to be bent. Rays of light are refracted at the water surface.

REFRACTION

The pencil in Figure 7.19 is straight but it seems to bend at the surface of the water. This happens because light waves in water travel more slowly than light waves in air. This change in speed as they leave the water causes the light waves to change direction. This change in direction is called refraction. All waves – light waves, sound waves, water waves – can be refracted.

EXTENSION WORK

Many optical instruments such as microscopes, telescopes and cameras use specially shaped pieces of glass or plastic (called lenses) to bend or refract light waves in a useful way.



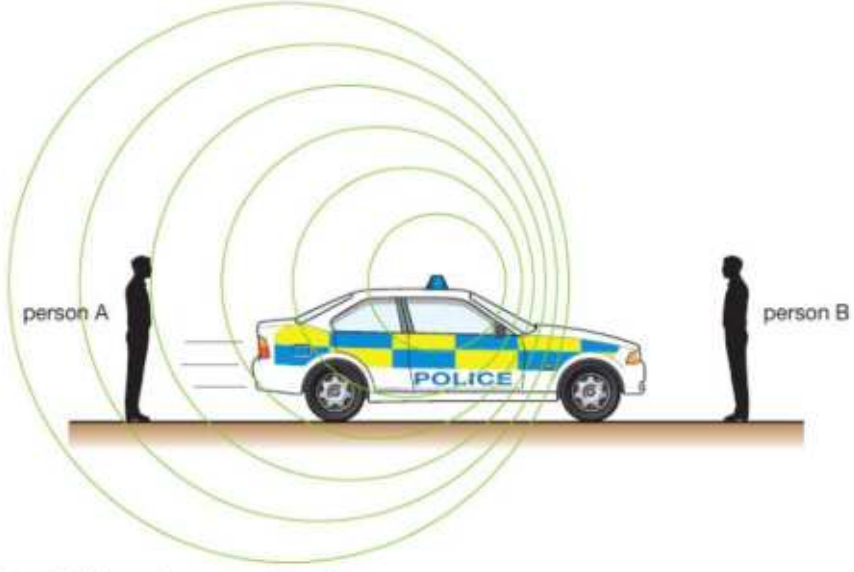
▲ Figure 7.20 In this camera, light waves are refracted by a glass lens to create a sharp image on the sensor or film. Refraction occurs because light travels more slowly in glass than in air.

THE DOPPLER EFFECT



▲ Figure 7.21 A stationary source of sound

When a car is not moving the sound waves we receive from its engine or from its horn arrive as a series of equally (evenly) spaced wavefronts. People in front of and behind the car hear sound of the same frequency and wavelength.



▲ Figure 7.22 A moving source of sound

If the car is moving, the wavefronts are no longer evenly spaced. Ahead of the car the wavefronts will be compressed as the car is moving in this direction. The waves will have a shorter wavelength and a higher frequency. Person B therefore hears a sound that has a higher **pitch** than when the car was stationary. Behind the car the waves are stretched out so person A hears a sound with a longer wavelength and lower frequency – that is, the pitch appears to have decreased.

These apparent changes in frequency, which occur when a source of waves is moving, is called the **Doppler effect** and is a property of all waves.

CHAPTER QUESTIONS

More questions on wave properties can be found at the end of Unit 3 on page 588.

SKILLS CRITICAL THINKING

1 a Explain the difference between a transverse wave and a longitudinal wave.

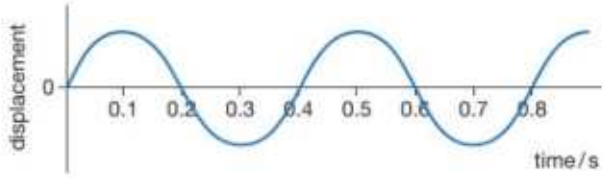
b Give one example of each.

SKILLS INTERPRETATION

c Draw a diagram of a transverse wave. On your diagram, mark the wavelength and amplitude of the wave.

SKILLS ANALYSIS, PROBLEM SOLVING

2 The diagram below shows the displacement of water as a wave travels through it.



From the diagram calculate:

a the period of the wave

b the frequency of the wave.

SKILLS PROBLEM SOLVING

3 The speed of sound in water is approximately 1500 m/s.

a What is the frequency of a sound wave with a wavelength of 1.5 m?

b What is the period of this wave?

SKILLS CRITICAL THINKING

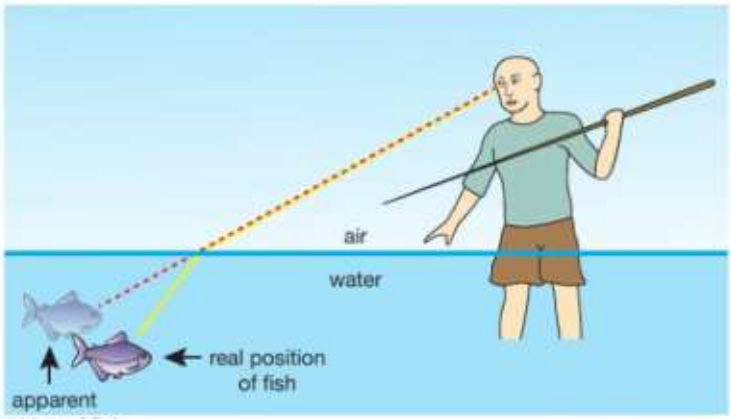
SKILLS REASONING

4 a Explain why the sound produced by the horn of an approaching car seems to have a higher frequency than one that is stationary.

b If the same car approached at a much higher speed how would this affect the frequency of the sound heard?

c Describe the frequency of the sound heard by the observer if the car is moving away at high speed.

5 Explain why this hunter should not aim at the fish he can see.



8 THE ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum is a family of waves, varying in wavelength and frequency. Although it is continuous, it is helpful to consider smaller groups of waves within the spectrum. These groups have distinct properties. As we will see in this chapter, understanding the different properties allows us to use these waves in many situations including cooking and communication.



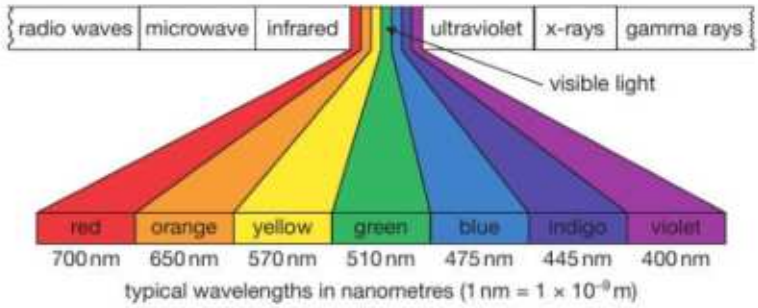
▶ Figure 8.1 When we shine white light through a prism it splits up forming a band of colours. This band is one small part of the electromagnetic spectrum.

LEARNING OBJECTIVES

- Know that light is part of a continuous electromagnetic spectrum that includes radio, microwave, infrared, visible, ultraviolet, x-ray and gamma ray radiations and that all these waves travel at the same speed in free space
- Know the order of the electromagnetic spectrum in terms of decreasing wavelength and increasing frequency, including the colours of the visible spectrum
- Explain some of the uses of electromagnetic radiations, including:
  - radio waves: broadcasting and communications
  - microwaves: cooking and satellite transmissions
  - infrared: heaters and night vision equipment
  - visible light: optical fibres and photography
  - ultraviolet: fluorescent lamps
  - x-rays: observing the internal structure of objects and materials, including for medical applications
  - gamma rays: sterilising food and medical equipment
- Explain the detrimental effects of excessive exposure of the human body to electromagnetic waves, including:
  - microwaves: internal heating of body tissue
  - infrared: skin burns
  - ultraviolet: damage to surface cells and blindness
  - gamma rays: cancer, mutation

  and describe simple protective measures against the risks

THE ELECTROMAGNETIC SPECTRUM



▲ Figure 8.2 The complete electromagnetic spectrum

The **electromagnetic spectrum** (EM spectrum) is a continuous spectrum of waves, which includes the visible spectrum. At one end of the spectrum the waves have a very long wavelength and low frequency, while at the other end the waves have a very short wavelength and high frequency. All the waves have the following properties:

1. They all transfer energy.
2. They are all transverse waves.
3. They all travel at 300 000 000 m/s, the speed of light in a **vacuum** (free space).
4. They can all be reflected and refracted.

Remember that the wave equations we met in the previous chapter can be applied to any member of the electromagnetic spectrum.

EXAMPLE 1

Yellow light has a wavelength of 5.7×10^{-7} m. What is the frequency and period of yellow light waves?

$$v = f \times \lambda$$

$$\text{So } f = \frac{v}{\lambda}$$

$$= \frac{3 \times 10^8 \text{ m/s}}{5.7 \times 10^{-7} \text{ m}}$$

$$= 5.26 \times 10^{14} \text{ Hz}$$

$$T = \frac{1}{f}$$

$$= \frac{1}{5.26 \times 10^{14} \text{ Hz}}$$

$$= 1.9 \times 10^{-15} \text{ s}$$

The table below shows the different groups of waves in order, and gives some of their uses.

	Typical frequency / Hz	Typical wavelength / m	Sources	Detectors	Uses
Radio waves	10^5–10^{10}	10^3–10^{-2}	radio transmitters, TV transmitters	radio and TV aerials	long-, medium- and short-wave radio, TV (UHF)
Microwaves	10^{10}–10^{11}	10^{-2}–10^{-3}	microwave transmitters and ovens	microwave receivers	mobile phone and satellite communication, cooking
Infrared (IR)	10^{11}–10^{14}	10^{-3}–10^{-6}	hot objects	skin, blackened thermometer, special photographic film	infrared cookers and heaters, TV and stereo remote controls, night vision
Visible light	10^{14}–10^{15}	10^{-6}–10^{-7}	luminous objects	the eye, photographic film, light-dependent resistors	seeing, communication (optical fibres), photography
Ultraviolet (UV)	10^{15}–10^{16}	10^{-7}–10^{-8}	UV lamps and the Sun	skin, photographic film and some fluorescent chemicals	fluorescent tubes and UV tanning lamps
X-rays	10^{16}–10^{18}	10^{-8}–10^{-10}	x-ray tubes	photographic film	x-radiography to observe the internal structure of objects, including human bodies
Gamma rays	10^{18}–10^{21}	10^{-10}–10^{-14}	radioactive materials	Geiger–Müller tube	sterilising equipment and food, radiotherapy

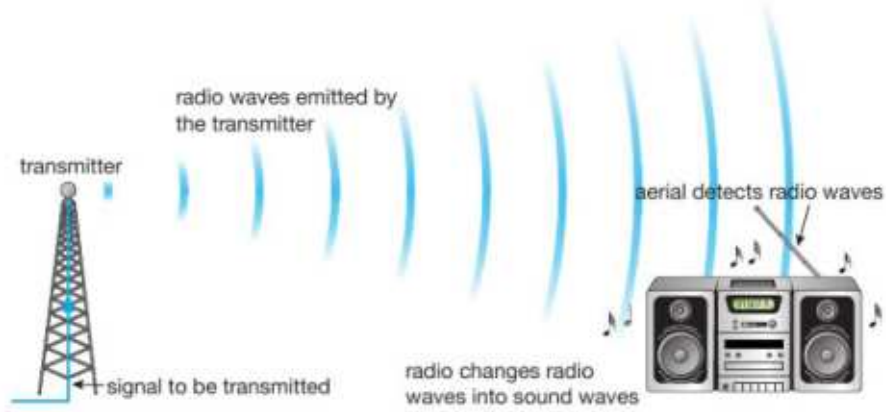
HINT

To remember the order of the waves in the electromagnetic spectrum try using 'Graham's Xylophone Uses Very Interesting Musical Rhythms'.

You do not need to remember the values of frequency and wavelength given in the table but you do need to know the order of the groups and which has the highest frequency or longest wavelengths. Most importantly, you need to realise that it is these differences in wavelength and frequency that give the groups their different properties – for example, gamma rays have the shortest wavelengths and highest frequencies, and carry the most energy.

RADIO WAVES

Radio waves have the longest wavelengths in the electromagnetic spectrum. They are used mainly for communication.



▲ Figure 8.3 Radio waves are emitted by a transmitter and detected by an aerial.

Radio waves are given out (**emitted**) by a transmitter. As they arrive at an aerial, they are detected and the information they carry can be received. Televisions and FM radios use radio waves with the shorter wavelengths to carry their signals.

MICROWAVES

Microwaves are used for communications, radar and cooking foods. Radar uses radio waves to find the position of things.



▲ Figure 8.4 Food cooks quickly in a microwave oven because water molecules in the food absorb the microwaves.

Food placed in a microwave oven cooks more quickly than in a normal oven. This is because water **molecules** in the food absorb the microwaves and become very hot. The food therefore cooks throughout rather than just from the outside.

Microwave ovens have metal screens that reflect microwaves and keep them inside the oven. This is necessary because if microwaves can cook food, they

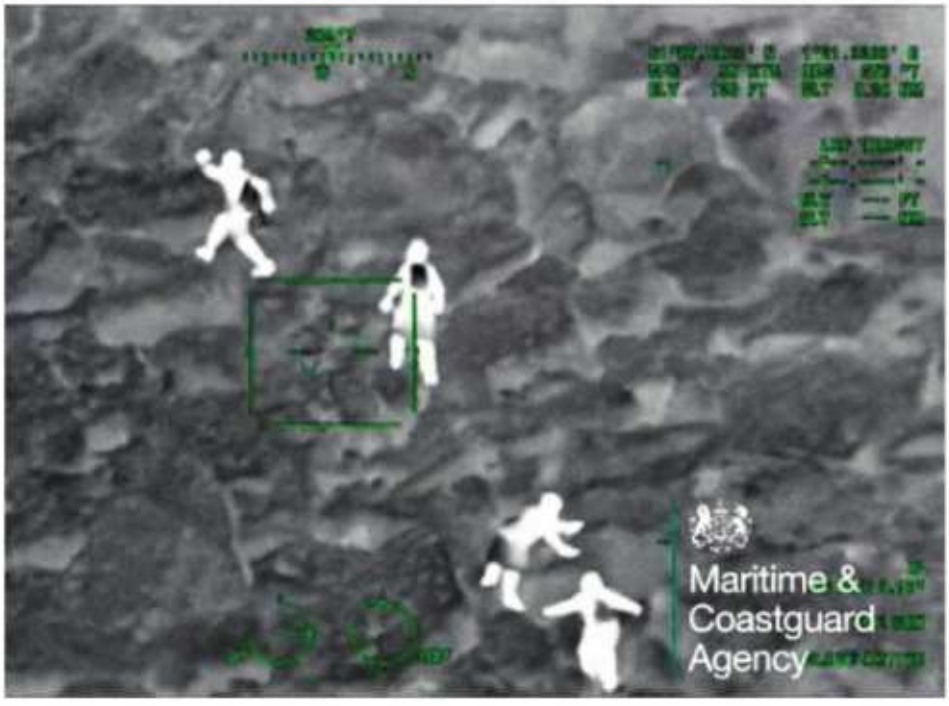
can also heat human body tissue! The microwaves used by mobile phones transmit much less energy than those used in a microwave oven, so they do not cook your brain when you use the phone.

Microwaves are used in communications. The waves pass easily through the Earth's atmosphere and so are used to carry signals to orbiting satellites. From here, the signals are passed on to their destination or to other orbiting satellites. Messages sent to and from mobile phones are also carried by microwaves. The fact that we are able to use mobile phones almost anywhere in the home and at work confirms that microwaves can pass through glass, brick and so on.

INFRARED

All objects, including your body, emit infrared (IR) radiation. The hotter an object is, the more energy it will emit as infrared. Energy is transferred by infrared radiation to bread in a toaster or food under a grill. Electric fires also transfer heat energy by infrared.

Special cameras designed to detect infrared waves can be used to create images even when there is no visible light. These cameras have many uses, including searching for people trapped in collapsed buildings, searching for criminals and checking for heat loss from buildings.



▲ Figure 8.5 It is not possible to see these people trapped at the bottom of a cliff using normal visible light. By using infrared detectors they can be found easily and rescued.

Infrared radiation is also used in remote controls for televisions, DVD players and stereo systems. It is very convenient for this purpose because the waves are not harmful. They have a low **penetrating power** and will therefore operate only over small distances, so they are unlikely to interfere with other signals or waves.

The human body can be harmed by too much infrared radiation, which can cause skin burns.



▲ Figure 8.6 Signals are carried from this remote control to a TV by infrared waves.

VISIBLE LIGHT

EXTENSION WORK

When talking about light and colour, we often refer to the seven colours in the visible spectrum. These colours are red, orange, yellow, green, blue, indigo and violet; red light has the longest wavelength and lowest frequency. If you look back at Figure 8.1, you may only be able to make out six colours – most people have difficulty separating indigo and violet (two types of purple). Sir Isaac Newton (1642–1727) discovered that 'white' light can be split up into different colours. He believed that the number seven had magical significance, and so he decided there were seven colours in the spectrum!



▲ Figure 8.7 Using visible light

This is the part of the electromagnetic spectrum that is visible to the human eye. We use it to see. Visible light from lasers is used to read compact discs and barcodes. It can also be sent along optical fibres, so it can be used for communication or for looking into hard-to-reach places such as inside the body of a patient (see page 583). Visible light can be detected by the sensors in digital cameras, and used to take still photographs or videos. Information stored on DVDs is also read using visible light.

ULTRAVIOLET LIGHT



▲ Figure 8.8 UV light can cause sunburn so we need to protect our skin.

Part of the light emitted by the Sun is ultraviolet (UV) light. UV radiation is harmful to human eyes and can damage the skin.

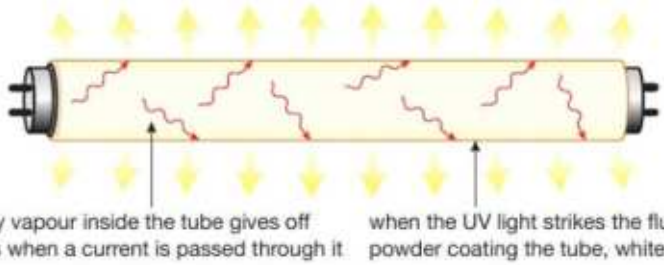
UV light causes the skin to tan, but overexposure (too much) will lead to sunburn and blistering. Ultraviolet radiation can also cause skin cancer and blindness. Protective goggles or glasses and skin creams can block the UV rays and will reduce the harmful effects of this radiation.

The **ozone layer** in the Earth's atmosphere absorbs large quantities of the Sun's UV radiation. In recent years there was real concern that the amount of ozone in the atmosphere was decreasing due to pollution, which would increase numbers of skin cancer. However, there is now evidence to show that the ozone layer is recovering.

Some chemicals glow (shine), or fluoresce, when under UV light. This property of UV light is used in security marker pens. The special ink is invisible in normal light but becomes visible in UV light.



▲ Figure 8.9 This red code is only visible under UV light.



▲ Figure 8.10 Fluorescent tubes glow when UV light hits the fluorescent coating in the tube.

Fluorescent tubes glow (shine) because the UV light they produce strikes a special coating (covering) on the inside of the tube, which then emits visible light.

X-RAYS

X-rays pass easily through soft body tissue but cannot pass through bones. As a result, radiographs or x-ray pictures can be taken to check a patient's bones.



▲ Figure 8.11 X-ray of a broken leg

Working with x-rays can cause cancer. Radiographers, who take x-rays, are at risk and have to stand behind lead screens or wear protective clothing.

X-rays are also used in industry to check the internal structures of objects – for example, to look for cracks and faults in buildings or machinery – and at airports as part of the security checking procedure.

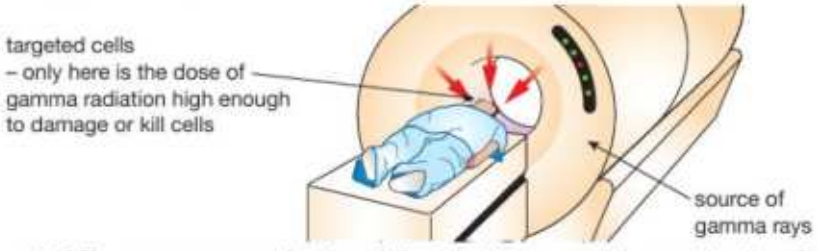


▲ Figure 8.12 X-rays were used to see what was in this suitcase.

GAMMA RAYS

Gamma rays, like x-rays, are highly penetrating rays and can cause damage to living cells. The damage can cause mutations (negative changes), which can lead to cancer. They are used to **sterilise** medical instruments, to kill microorganisms so that food will keep for longer and to treat cancer using radiotherapy. Gamma rays can both cause and cure cancer. Large doses of gamma rays targeted directly at the cancerous growth can be used to kill the cancer cells completely.

Like x-rays the use of lead screens, boxes and aprons can prevent the damage caused by gamma rays (overexposure).



▲ Figure 8.13 The gamma rays are aimed carefully so that they cross at the exact location of the cancerous cells.

CHAPTER QUESTIONS

More questions on using waves can be found at the end of Unit 3 on page 588.

SKILLS CRITICAL THINKING 

1 a Name four wave properties that are common to all members of the electromagnetic spectrum.

b Name three types of wave that can be used for communicating.

c Name two types of wave that can be used for cooking.

d Name one type of wave that is used to treat cancer.

e Name one type of wave that might be used to 'see' people in the dark.

f Name one type of wave that is used for radar.

SKILLS REASONING 

2 Explain why:

a microwave ovens cook food much more quickly than normal ovens

b x-rays are used to check for broken bones

c it is important not to damage the ozone layer around the Earth

d food stays fresher for longer after it has been exposed to gamma radiation.

3 a Explain one way in which you could prevent overexposure (damage) by the following waves:

i x-rays

ii ultraviolet waves.

SKILLS CRITICAL THINKING

b Select one of the above waves and then describe one consequence of overexposure.

SKILLS INTERPRETATION 

4 Copy and complete the table below for four more different wave groups within the electromagnetic spectrum.

Type of radiation	Possible harm	Precautions
x-rays	cancer	lead screening

9 LIGHT AND SOUND WAVES

We see objects because they emit or reflect light. In this chapter you will learn how light behaves when it reflects from different surfaces, and what happens when light travels from one transparent material to another. Sound waves are longitudinal waves and not transverse waves like light. Nevertheless they can be reflected and refracted in just the same way. In this chapter you will learn about the nature and behaviour of sound waves, and how we make use of them in our everyday lives.



▲ Figure 9.1 In the Hall of Mirrors at the fairground the reflection of light can be very confusing!

LEARNING OBJECTIVES

- Know that light waves are transverse waves and that they can be reflected and refracted
- Use the law of reflection (the angle of incidence equals the angle of reflection)
- Draw ray diagrams to illustrate reflection and refraction
- Practical: investigate the refraction of light, using rectangular blocks, semi-circular blocks and triangular prisms
- Know and use the relationship between refractive index, angle of incidence and angle of refraction:

$$n = \frac{\sin i}{\sin r}$$

- Practical: investigate the refractive index of glass, using a glass block
- Describe the role of total internal reflection in transmitting information along optical fibres and in prisms
- Explain the meaning of critical angle c
- Know and use the relationship between critical angle and refractive index:

$$\sin c = \frac{1}{n}$$

- Know that sound waves are longitudinal waves that can be reflected and refracted

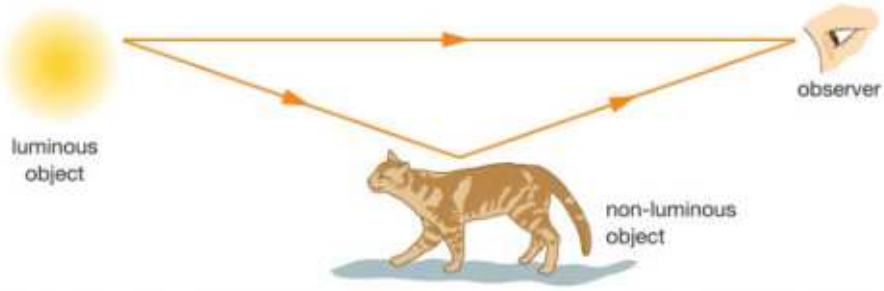


▲ Figure 9.2 Cataracts mean that light cannot enter the eye correctly.

SEEING THE LIGHT

The patient shown in Figure 9.2 has a cataract. The front of one of his eyes has become so cloudy that he is unable to see. Nowadays it is possible to remove this damaged part of the eye and replace it with a clear plastic that will allow light to enter the eye again.

There are many sources of light, including the Sun, the stars, fires, light bulbs and so on. Objects such as these that emit their own light are called luminous objects. When the emitted light enters our eyes we see the object. Most objects, however, are non-luminous. They do not emit light. We see these non-luminous objects because of the light they reflect.



▲ Figure 9.3 Luminous objects, such as the Sun, give out light. Non-luminous objects only reflect light.

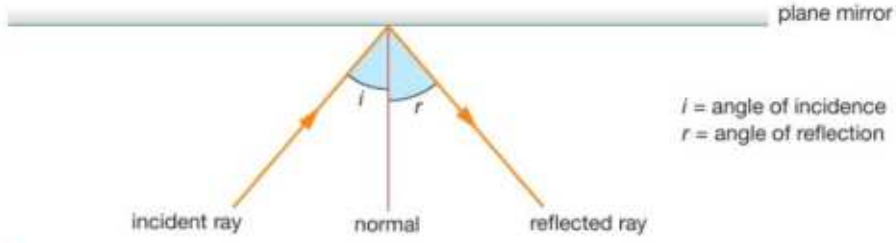
REFLECTION

When a ray of light strikes a plane (flat) mirror, it is reflected so that the angle of incidence (i) is equal to the angle of reflection (r).

KEY POINT

The angle of incidence is the angle between the incident ray and the normal.

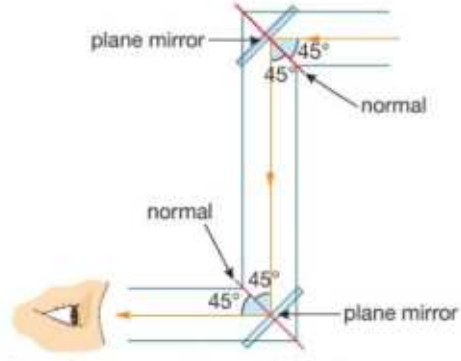
The angle of reflection is the angle between the reflected ray and the normal.



▲ Figure 9.4 Light is reflected from a plane mirror. The angle of incidence is equal to the angle of reflection. The normal is a line at right angles to the mirror.

Mirrors are often used to change the direction of a ray of light. One example of this is the simple periscope, which uses two mirrors to change the direction of rays of light.

Rays from the object strike the first mirror at an angle of 45° to the normal. The rays are reflected at 45° to the normal and so are turned through an angle of 90° by the mirror. At the second mirror the rays are again turned through 90°. Changing the direction of rays of light in this way allows an observer to use a periscope to see over or around objects.



▲ Figure 9.5 A periscope is used to see over or around objects.

REFRACTION



▲ Figure 9.6 This rainbow is caused by refraction.

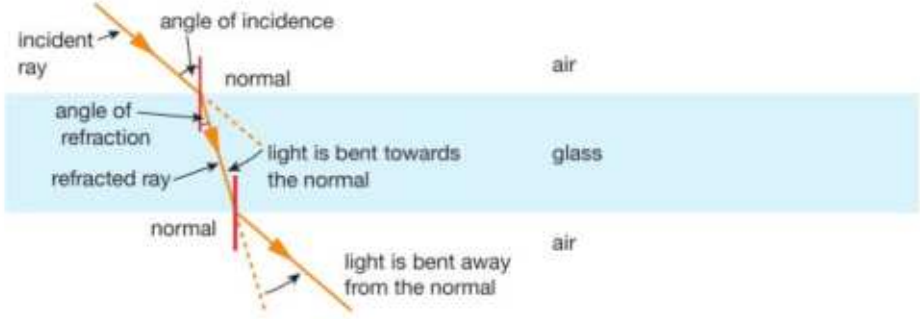
KEY POINT

A medium is a material, such as glass or water, through which light can travel. The plural of medium is media.

KEY POINT

Light does travel more slowly in air than in a vacuum but the difference is tiny.

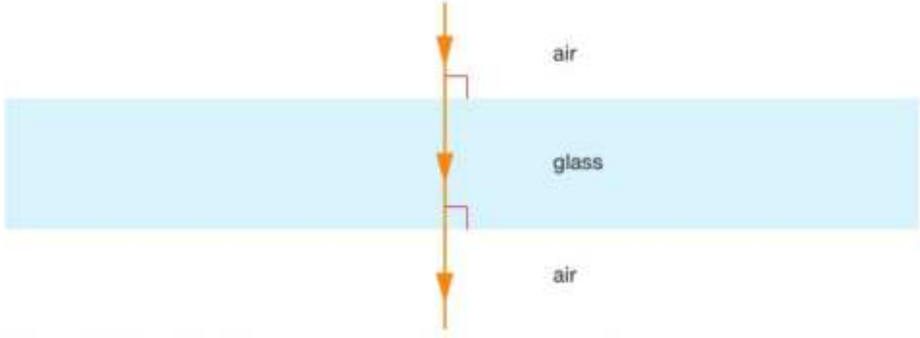
Rays of light can travel through many different transparent media, including air, water and glass. Light can also travel through a vacuum. In a vacuum and in air, light travels at a speed of 300 000 000 m/s. In other media it travels more slowly. For example, the speed of light in glass is approximately 200 000 000 m/s. When a ray of light travels from air into glass or water it slows down as it crosses the border between the two media. This change in speed may cause the ray to change direction. This change in direction of a ray is called refraction.



▲ Figure 9.7 This light ray is being refracted twice – once as it travels from air into glass and then as it travels from glass to air.

As a ray enters a glass block, it slows down and is refracted towards the normal. As the ray leaves the block it speeds up and is refracted away from the normal.

If the ray strikes the boundary between the two media at 90°, the ray continues without change of direction (Figure 9.8).



▲ Figure 9.8 If the light hits the boundary at 90° the ray does not bend.

REFRACTIVE INDEX

Different materials can bend rays of light by different amounts. We describe this by using a number called the **refractive index** (n). The refractive index of glass is about 1.5 and water is 1.3. This tells us that under similar circumstances glass will refract light more than water.

We can use the equation below to calculate the refractive index of a material:

$$n = \frac{\sin i}{\sin r}$$

where i is the angle of incidence and r is the **angle of refraction**.

EXAMPLE 1

In an experiment similar to the one shown in Figure 9.9, the angle of incidence was measured as 30° and the angle of refraction as 19°. Calculate the refractive index of the glass block.

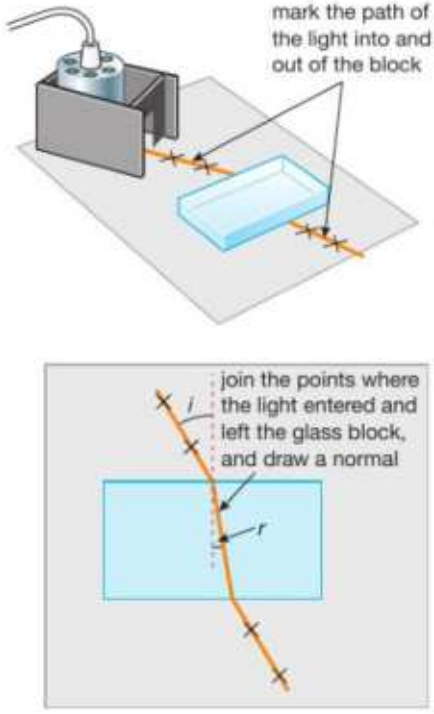
$$n = \frac{\sin i}{\sin r}$$

$$= \frac{\sin 30}{\sin 19}$$

$$= \frac{0.5}{0.33}$$

$$= 1.52$$

Safety note: Ray box lamps get hot enough to burn skin and char paper. Glass blocks and prisms should be handled carefully and not knocked together – they can splinter or shatter.



▲ Figure 9.9 How to investigate refraction using a rectangular glass block

ACTIVITY 1

▼ PRACTICAL: INVESTIGATE THE REFRACTIVE INDEX FOR GLASS

You can investigate the refractive index of glass using a ray box and a rectangular glass block.

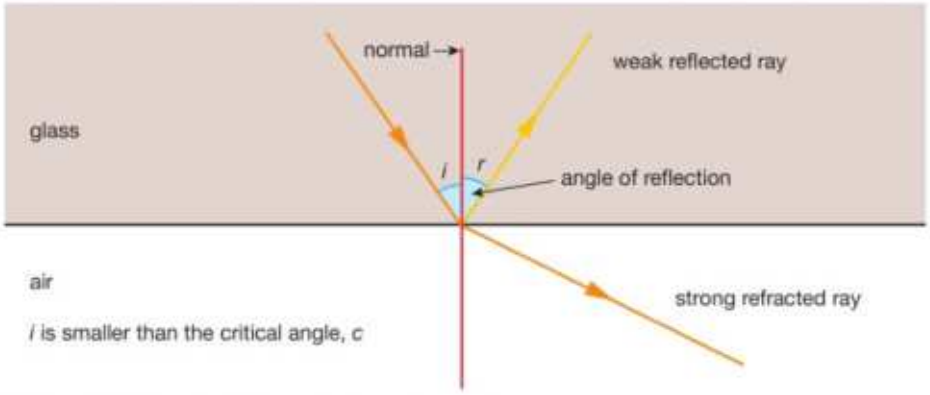
1. Shine a ray of light onto one of the sides of the glass block, so that the ray emerges on the opposite side of the block. Mark the directions of both of these rays with crosses.
2. Draw around the glass block before removing it.
3. Using the crosses, draw in the direction of both rays.
4. Draw in the direction of the ray that travelled inside the glass block.
5. Draw a normal (a line at 90° to the glass surface) where the ray enters the block.
6. Measure the angles of incidence (i) and refraction (r) (see Figure 9.9).
7. Use the equation $n = \frac{\sin i}{\sin r}$ to find the refractive index of the glass block.

TOTAL INTERNAL REFLECTION

When a ray of light with a small angle of incidence passes from glass into air, most of the light is refracted away from the normal but if we look carefully we can see that there is a small amount that is reflected from the boundary. Total internal reflection only occurs when rays of light are travelling towards a boundary with a less optically dense medium (a medium with a lower refractive index).

KEY POINT

The symbol '*r*' is used for both the angle of reflection and the angle of refraction.

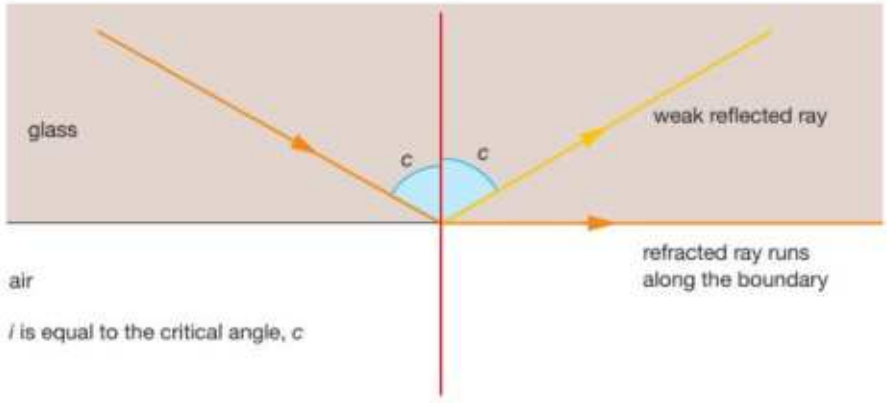


▲ Figure 9.10 A ray of light travelling from glass to air

But as the angle of incidence in the glass increases, the angle of refraction also increases until it reaches a special angle called the critical angle (*c*). The angle of refraction now is 90°.

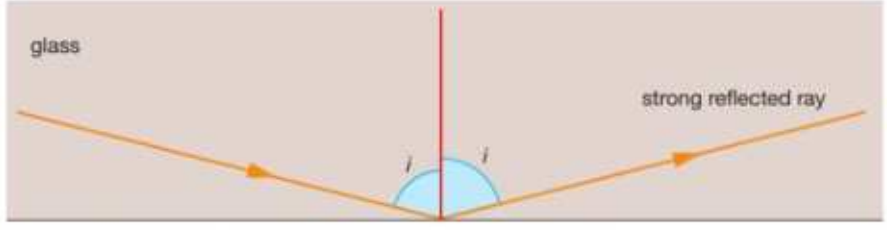
The critical angle is the smallest possible angle of incidence at which light rays are totally internally reflected.

a



▲ Figure 9.11a Ray of light strikes glass/air boundary at the critical angle

b



▲ Figure 9.11b When *i* is greater than *c* total internal reflection occurs.

When *i* is greater than the critical angle, all the light is reflected at the boundary. No light is refracted. The light is totally internally reflected.

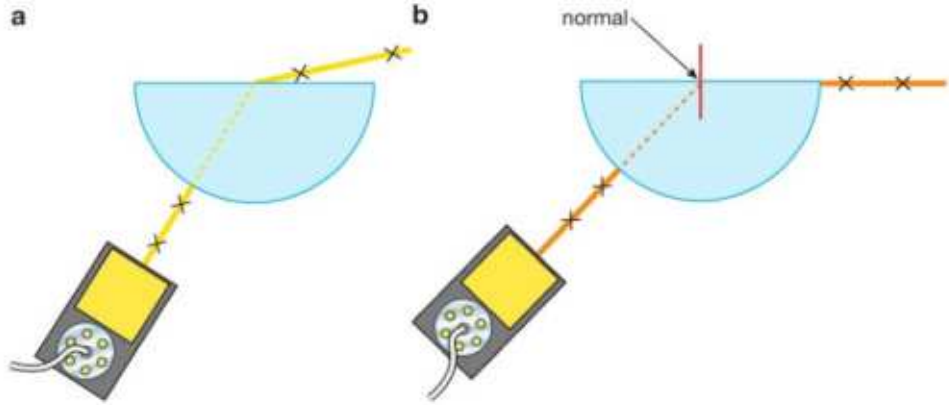
ACTIVITY 2

▼ PRACTICAL: INVESTIGATE TOTAL INTERNAL REFLECTION

You can investigate total internal reflection in the laboratory using a semi-circular glass block and a ray box. As shown in Figure 9.12a, a ray of light is directed at the centre of the straight side of the block through the curved side. (We do this because the incident ray will then always hit the edge of the glass block at 90°, so there are no refraction effects to take into account as the light goes into the block.)

Now by carefully increasing and decreasing the angle at which the ray strikes the flat edge of the glass block, we can discover the smallest angle at which most of the light is refracted along the edge of the glass block (see Figure 9.12b). This angle is the critical angle.

Safety note: Ray box lamps get hot enough to burn skin and char paper. Glass blocks and prisms should be handled carefully and not knocked together – they can splinter or shatter.



▲ Figure 9.12 **a** A semi-circular glass block used to demonstrate total internal reflection **b** Light striking the edge of the glass block at the critical angle

For light passing from glass to air, the critical angle is typically 42° and the critical angle for light passing from water to air is 49°.

The critical angle for a particular medium is related to its refractive index by this equation:

$$\sin c = \frac{1}{n}$$

EXAMPLE 2

The refractive index for a type of glass is 1.45. Calculate the critical angle.

$$\sin c = \frac{1}{n}$$

$$\sin c = \frac{1}{1.45}$$

$$\sin c = 0.69$$

$$c = 43.6°$$

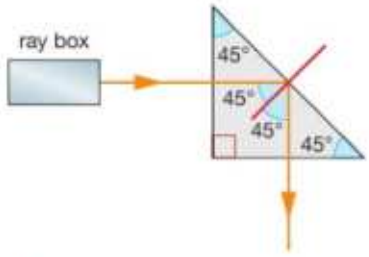
We sometimes use **prisms** rather than mirrors to reflect light. The light is totally internally reflected by the prism.

Safety note: Ray box lamps get hot enough to burn skin and char paper. Glass blocks and prisms should be handled carefully and not knocked together – they can splinter or shatter.

ACTIVITY 3

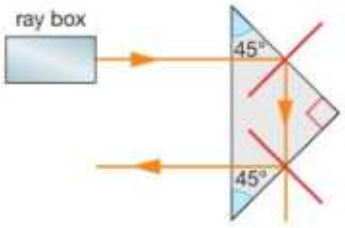
▼ PRACTICAL: INVESTIGATE TOTAL INTERNAL REFLECTION IN PRISMS

If you shine a ray of light into a prism as shown in Figure 9.13 it will strike the far surface at an angle of 45°. The critical angle for glass is about 42° so the ray will be totally internally reflected. You will see therefore that the ray will be reflected through an angle of 90°.



▲ Figure 9.13 Turning through 90° using total internal reflection

If you shine a ray into the prism as shown in Figure 9.14 the ray will be reflected through an angle of 180° – that is, it will go back in the direction from which it came.

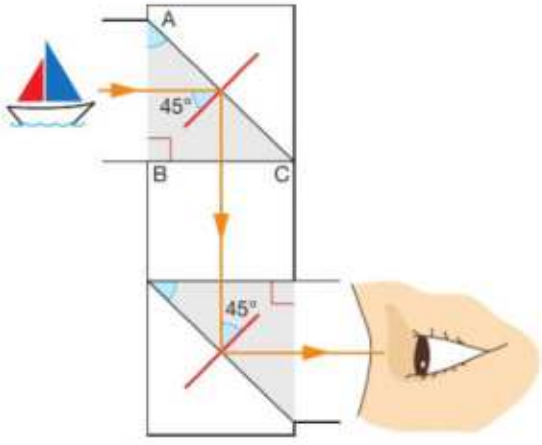


▲ Figure 9.14 Turning through 180° using total internal reflection

USING TOTAL INTERNAL REFLECTION

THE PRISMATIC PERISCOPE

The images produced by prisms are often brighter and clearer than those produced by mirrors. A periscope that uses prisms to reflect the light is called a prismatic periscope. Light passes through the surface AB of the first prism at 90° and so does not change direction (it is undeviated). It then strikes the surface AC of the prism at an angle of 45°. The critical angle for glass is 42° so the ray is totally internally reflected and is turned through 90°. When it leaves the first prism the light travels to a second prism. The second prism is positioned so that the ray is again totally internally reflected. The ray emerges parallel to the direction in which it was originally travelling.



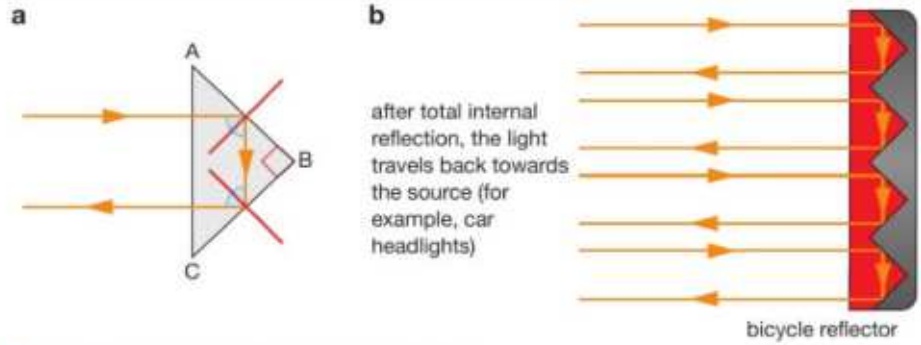
▲ Figure 9.15 Total internal reflection in a prismatic periscope

BICYCLE AND CAR REFLECTORS



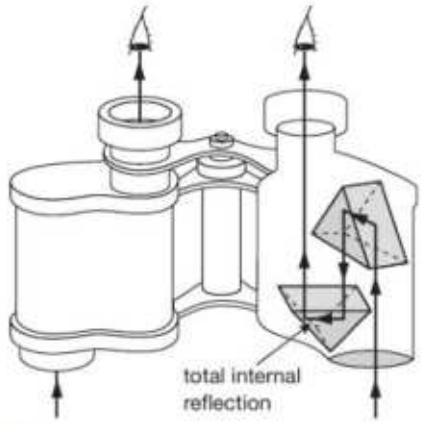


▲ Figure 9.17 Reflectors like these can save lives.



▲ Figure 9.16 Prisms can also be used as reflectors.

Light entering the prism in Figure 9.16 is totally internally reflected twice. It emerges from the prism travelling back in the direction from which it originally came. This arrangement is used in bicycle or car reflectors.



▲ Figure 9.18 Total internal reflection inside binoculars



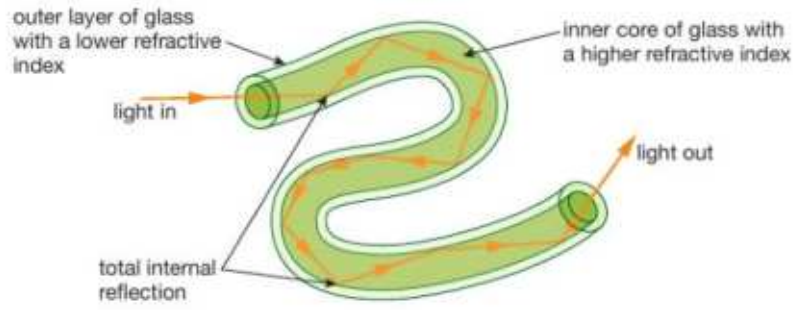
▲ Figure 9.19 Prismatic binoculars

Binoculars also make use of total internal reflection within prisms.

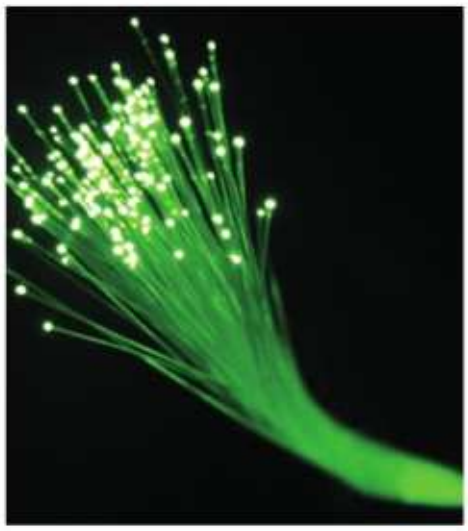
Each side of a pair of binoculars contains two prisms to totally internally reflect the incoming light. Without the prisms, binoculars would have to be very long to obtain large **magnifications** and would look like a pair of telescopes.

OPTICAL FIBRES

One of the most important **applications** for total internal reflection is the optical fibre. This is a very thin piece of fibre composed of two different types of glass. The centre is made of a glass that has a high refractive index surrounded by a different type of glass that has a lower refractive index.



▲ Figure 9.20 In an optical fibre, light undergoes total internal reflection.



▲ Figure 9.21 Optical fibres

As the fibres are very narrow, light entering the inner **core** always strikes the boundary of the two glasses at an angle that is greater than the critical angle. No light escapes across this boundary. The fibre therefore acts as a 'light pipe' providing a path that the light follows even when the fibre is curved.

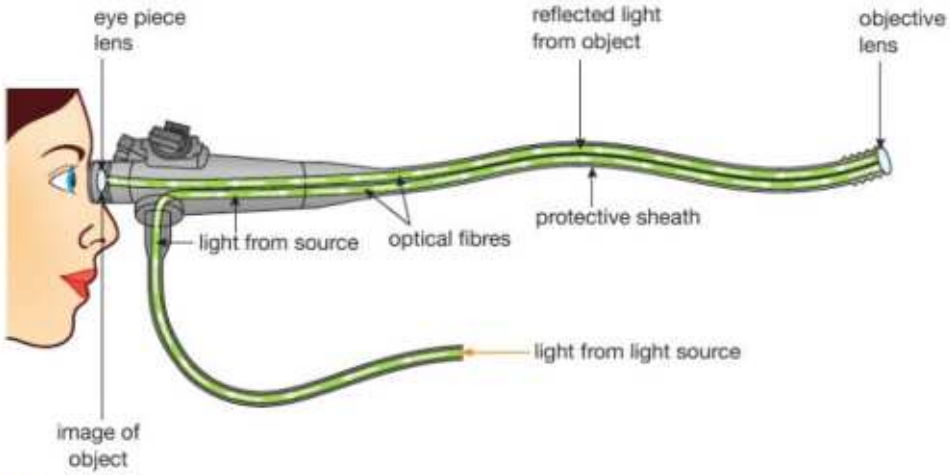
Large numbers of these fibres fixed together form a bundle. Bundles can carry sufficient light for images of objects to be seen through them. If the fibres are tapered (narrower at one end) it is also possible to produce a magnified image.

Figure 9.22 shows optical fibres in an endoscope. The endoscope is used by doctors to see the inside the body – for example, to examine the inside of the stomach. Endoscopes can also be used by engineers to see hard-to-reach parts of machinery.

Light travels down one bundle of fibres and shines on the object to be viewed. Light reflected by the object travels up a second bundle of fibres. An image of the object is created by the eyepiece.

THE ENDOSCOPE

By using optical fibres to see what they are doing, doctors can carry out operations through small holes made in the body, rather than through large cuts. This is called 'keyhole surgery'. This is less stressful for patients and usually leads to a more rapid recovery.



▲ Figure 9.22 Optical fibres are used in endoscopes to see inside the body.

OPTICAL FIBRES IN TELECOMMUNICATIONS

Modern telecommunications systems use optical fibres rather than copper wires to transmit messages as less energy is lost. Electrical signals from a telephone are converted into light energy produced by tiny lasers, which send pulses (small amounts) of light into the ends of optical fibres. A light-sensitive detector at the other end changes the pulses back into electrical signals, which then flow into a telephone receiver (ear piece).

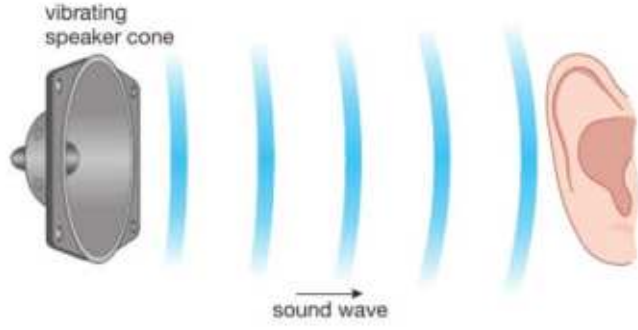
SOUND WAVES

Figure 9.23 shows part of the sound system used by a band playing at a concert. This equipment must produce sounds that are loud enough to be heard by all the audience and the sound quality must be good enough for the music to be appreciated. We are going to look at how sounds are made and how they travel as waves.



▲ Figure 9.23 The sound produced by the speakers must be loud but also of good quality.

Sounds are produced by objects that are vibrating. We hear sounds when these vibrations, travelling as sound waves, reach our ears.

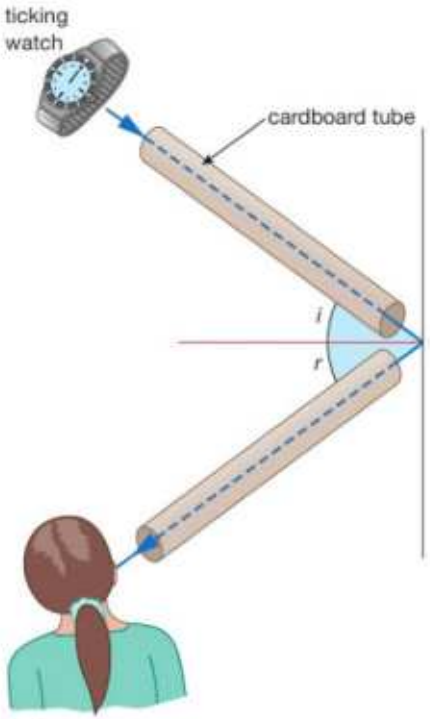


▲ Figure 9.24 The loudspeaker vibrates and produces sound waves.

EXTENSION WORK

You will not be tested on this more detailed description of how sounds from a loudspeaker are heard. As the speaker cone moves to the right, it pushes air molecules closer together, creating a **compression**. These particles then push against neighbouring particles so that the compression appears to be moving to the right. Behind the compression as the speaker cone moves to the left is a region where the particles are spread out. This region is called a rarefaction. After the cone has vibrated several times, it has created a series of compressions and rarefactions travelling away from it. This is a longitudinal sound wave (see page 560). When the waves enter the ear, they strike the eardrum and make it vibrate. These vibrations are changed into electrical signals, which are then detected by the brain.

REFLECTION



▲ Figure 9.25 Sound waves are reflected in the same way that light rays are reflected.

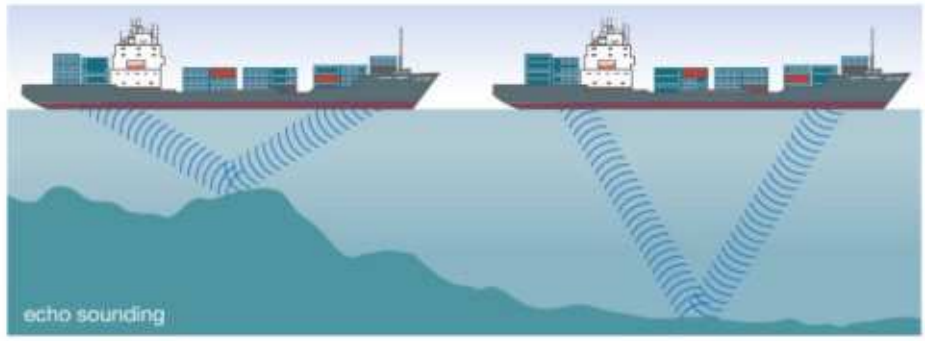
Sound waves behave in the same way as any other wave.

When a sound wave strikes a surface it may be reflected. Like light waves, sound waves are reflected from a surface so that the angle of incidence is equal to the angle of reflection (see Figure 9.25).

Ships often use echoes to discover the depth of the water beneath them. This is called echo sounding.

1. Sound waves are emitted from the ship and travel to the seabed (sea floor).
2. Some of these waves are reflected from the seabed back up to the ship.
3. Equipment on the ship detects these sound waves.
4. The time it takes the waves to make this journey is measured.
5. Knowing this time, the depth of the sea below the ship can be calculated.

The system of using echoes in this way is called **sonar** (Sound, Navigation And Ranging).

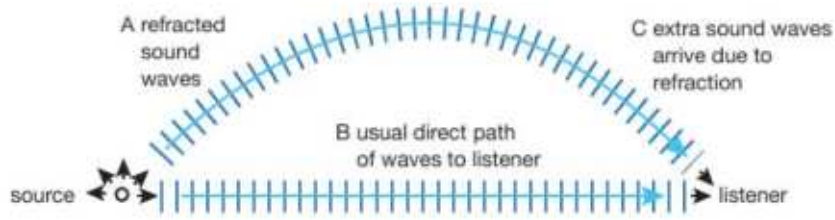


▲ Figure 9.26 Reflected sound can be used to tell ships about the depth of the sea beneath them.

REFRACTION OF SOUND

All waves can be refracted, even sound waves! For example, if some parts of a sound wave are travelling through warm air, they will travel more quickly than those parts travelling through cooler air. As a result the direction of the sound wave will change. It will be refracted.

Although it is not possible to see sound waves being refracted, we can sometimes hear their effect. Standing at the edge of a large pond or lake we can sometimes hear sounds from things on the other side of the water much more clearly than we would expect. This is due to refraction. Figure 9.27 explains how this happens.



▲ Figure 9.27 Why sometimes sounds travelling across water are louder than we expect

1 Most of the sound we hear travels to us in a straight line (Path B).

2 But some sound travels upwards (Path A).

3 If the temperature conditions are right, then as the sound waves travel through the air they are refracted and follow a curved path downwards (Path C).

4 We now receive two sets of sound waves.

5 So the sound we hear seems louder and clearer.

CHAPTER QUESTIONS

More questions on refraction can be found at the end of Unit 3 on page 588.

SKILLS INTERPRETATION, PROBLEM SOLVING

1 Draw a ray diagram to show how a ray of light can be turned through 100° using two plane mirrors. Mark on your diagram a value for the angle of incidence at each of the mirrors.

SKILLS INTERPRETATION

2 a Draw a diagram to show the path of a ray of light travelling from air into a rectangular glass block at an angle of about 45°.

b Show the path of the ray as it emerges from the block.

SKILLS CRITICAL THINKING

c Explain why the ray changes direction each time it crosses the air/glass boundary.

SKILLS INTERPRETATION

d Draw a second diagram showing a ray that travels through the block without its direction changing.

SKILLS PROBLEM SOLVING

3 In an experiment to measure the refractive index of a type of glass, the angle of refraction was found to be 31° when the angle of incidence was 55°.

a Calculate the refractive index of the glass.

b What would the angle of refraction be for a ray with an angle of incidence of 45°?

c Calculate the critical angle for the glass.

SKILLS INTERPRETATION

4 a Draw a diagram to show how a prism can create a rainbow of colours.

SKILLS CRITICAL THINKING

b Explain how these colours are produced by the prism.

SKILLS INTERPRETATION

5 Draw three ray diagrams to show what happens to a ray of light travelling in a glass block in the following situations. It hits a face of the block at an angle:

a less than the critical angle

b equal to the critical angle

c greater than the critical angle.

SKILLS CRITICAL THINKING

SKILLS INTERPRETATION

SKILLS REASONING

SKILLS INTERPRETATION

SKILLS INTERPRETATION, CRITICAL THINKING

SKILLS CRITICAL THINKING

6 a What is meant by 'total internal reflection of light' and under what conditions does it occur?

b Draw a diagram to show how total internal reflection takes place in a prismatic periscope.

c Give one advantage of using prisms in a periscope rather than plane mirrors.

d Draw a second diagram to show how a prism could be used to turn a ray of light through 180°. Give one application of a prism used in this way.

7 a Explain why a ray of light entering an optical fibre is unable to escape through the sides of the fibre. Include a ray diagram in your explanation.

b Explain how doctors use optical fibres to see inside the body.

c Name one other use of optical fibres.

UNIT QUESTIONS

SKILLS CRITICAL THINKING

1 a Which of the following does not move as a transverse wave?

A ultraviolet light
B sound wave
C surface water wave
D microwave

(1)

b Which of these effects describes the change in pitch we hear when a fast moving motorbike goes past?

A total internal reflection
B refraction
C reflection
D Doppler

(1)

c Which of the following does not make use of total internal reflection?

A oscilloscope
B endoscope
C prismatic periscope
D optical fibres

(1)

(Total 3 marks)

SKILLS INTERPRETATION

2 The diagram below shows the cross-section of a water wave.



a Copy this diagram and mark on it:

i the wavelength of the wave (λ) **(1)**

ii the amplitude of the wave (A). **(1)**

SKILLS PROBLEM SOLVING

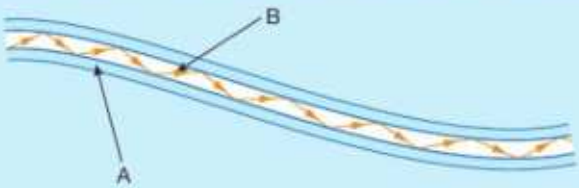
b i A water wave travelling at 20 m/s has a wavelength of 2.5 m. Calculate the frequency of the wave. **(3)**

ii Calculate the time period of the above wave. **(1)**

(Total 6 marks)

SKILLS ANALYSIS

3 The diagram below shows a ray of light travelling down an optical fibre.



SKILLS ANALYSIS

a What is A? (1)

b What is B? (1)

c Why is light reflected from the boundary between A and B? (2)

SKILLS CRITICAL THINKING

d Describe one medical use for optical fibres. (1)

(Total 5 marks)

4

a i Explain the difference between a longitudinal wave and a transverse wave. (1)

ii Give one example of each type of wave. (2)

A girl stands 500 m from a tall building and bangs two pieces of wood together. At the same moment her friend starts a stopwatch. The sound waves created by the two pieces of wood hit the building and are reflected. When the two girls hear the echo they stop the stopwatch and note the time. The girls repeat the experiment four more times. The results are shown in the table below.

Experiment	Time (seconds)
1	2.95
2	3.00
3	2.90
4	3.20
5	2.95

SKILLS EXECUTIVE FUNCTION

b Why did the girls repeat the experiment five times? (1)

SKILLS PROBLEM SOLVING

c Calculate the speed of sound using the results. (6)

SKILLS EXECUTIVE FUNCTION

d One of the girls thought that their answer might be affected by wind. Was she correct? Explain your answer. (2)

(Total 12 marks)

SKILLS CRITICAL THINKING

5

The electromagnetic spectrum contains the following groups of waves: infrared, ultraviolet, x-rays, radio waves, microwaves, visible spectrum and gamma rays.

a Put these groups of waves in the order they appear in the electromagnetic spectrum starting with the group that has the longest wavelength. (2)

b Write down four properties that all of these waves have in common. (4)

c Write down one use for each group of waves. (7)

d Which three groups of waves could cause cancer? (3)

e Which three groups of waves can be used to communicate (3)

(Total 19 marks)

SKILLS PROBLEM SOLVING

6

a A ray of light hits the outside surface of a glass block with an angle of incidence of 38°. Its angle of refraction inside the block is 24°.

i Calculate the refractive index of the glass. (4)

ii Calculate the critical angle for this glass. (2)

b Calculate the refractive index for a piece of glass whose critical angle is 42°. (3)

(Total 9 marks)

PHYSICS UNIT 4 ENERGY RESOURCES AND ENERGY TRANSFER

Energy, energy resources and the transfer of energy! These are all vital to modern life.

The photo shows energy produced from a wind farm. We also obtain energy by burning fossil fuels like coal and oil, directly from the Sun in the form of heat, from hydroelectric power and nuclear power, and from many other resources.

We need to understand how to transfer energy from one store to another, to use it efficiently and to conserve resources that cannot be replaced. We also need to be aware of the advantages and disadvantages of different energy resources.

Physics is about energy!



10 ENERGY TRANSFERS

Whenever anything happens, energy is transferred from one store to another – indeed, without energy things simply can't happen! In this chapter, you will learn that energy can be transferred to many different stores, including sound, light, movement, thermal and potential energy. You will also find out that, although energy is never destroyed, in every energy transfer some energy is transferred to the surroundings, often as thermal energy.



▲ Figure 10.1 Energy is stored as sound, movement and light, for example.

LEARNING OBJECTIVES

- Describe energy transfers involving energy stores:
  - energy stores: chemical, kinetic, gravitational, elastic, thermal, magnetic, electrostatic, nuclear
  - energy transfers: mechanically, electrically, by heating, by radiation (light and sound)
- Use the principle of conservation of energy
- Know and use the relationship between efficiency, useful energy output and total energy output:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy output}} \times 100\%$$

- Describe a variety of everyday and scientific devices and situations, explaining the transfer of the input energy in terms of the above relationship, including their representation by Sankey diagrams

UNITS

In this section you will need to use kilogram (kg) as the unit of mass, joule (J) as the unit of energy, metre (m) as the unit of length, metre per second (m/s) as the unit of speed and velocity, metre per second squared (m/s^2) as the unit of acceleration, newton (N) as the unit of force, second (s) as the unit of time and watt (W) as the unit of power. You have used all these units before.

For things to happen we need energy! Energy is used to produce sound. Energy is used to transport people and goods from place to place, whether it is by train, boat or plane or on the backs of animals or even by bicycles. Energy is needed to lift objects, make machinery work and run all the electrical and electronic equipment we have in our modern world. Energy is transferred by heating and as light radiation. The demand for energy increases every day because the world's population is increasing. People consume energy in the form of food and need energy for the basics of life, like warmth and light. As people become wealthier they demand much more than the basics, so the need for energy grows!

STORES OF ENERGY

Energy is found in many different stores:

- We get our energy from the food we eat. Food provides stored chemical energy that we can burn to transfer it to other types of energy.
- We use the energy from food to generate **thermal** energy (heat energy) to help to keep us warm.

EXTENSION WORK

Sound energy can be used to break up small stones that can form inside a person's body, without the need for an operation. Sound energy is also used in medicine to examine the inside of the body, as an alternative to x-rays.

- Our muscles transfer the chemical energy to movement energy (kinetic energy).
- Some of this movement energy is transferred to other stores by the radiation of sound.
- We need to transfer energy by heating to our homes, schools and workplaces. We also transfer energy in the form of light waves to illuminate our buildings, vehicles and roads.
- Most of the energy needed for these purposes is transferred electrically. The energy stores that are used in the production of electricity include chemical (burning gas, coal or oil) and nuclear.
- Some electrical energy is produced from the gravitational potential energy in water kept in reservoirs in mountainous areas. We can also use the energy in the hot core (centre) of the Earth. We see the evidence of this huge supply of heat in volcanoes and thermal springs.
- Energy from the thermal energy store underground is called geothermal energy.
- Energy can also be stored in springs as elastic potential energy. This type of stored energy is used in things like clocks and toys.

The main resource of energy for the Earth is our Sun. This provides us with heat, light and other stores of energy.

ENERGY TRANSFERS

For energy to be useful, we need to be able to transfer it from one store into whichever store we require. Unfortunately, when we try to do this there is usually some energy transferred to unwanted stores. We often refer to these energy transfers to unwanted stores as 'wasted' energy because it is not being used for a useful purpose.

Here are some examples of wasted energy:

- Energy can be transferred electrically to hot water in a tank (a thermal energy store) in a house to be used when needed. Although the tank may be well insulated, some energy will be transferred from the water in the hot water tank by heating other objects like the metal tank and then the surrounding air. These are unwanted energy stores.
- We provide our cars with an energy store, the tank of petrol (gas). We want energy from this store to be transferred to the kinetic energy of the moving car, and to gravitational energy if we are driving up a hill – both transfers are useful. Heating will also transfer thermal energy to the surroundings, sound will radiate energy to the surroundings and friction between moving parts and the air will cause mechanical work to be done making things get hot therefore transferring thermal energy to the surroundings. These are examples of chemical energy stored in the fuel being transferred to unwanted energy stores.

Unwanted energy transfers reduce efficiency. This problem is the same whether the system is a small one, like a car, or a large system, like the nationwide electricity generation and distribution industry. We need to be aware of where our energy is transferring to if we are to find ways of using it well.

SOME ENERGY TRANSFERS

We have many ways of transferring energy from one store to another.



▲ Figure 10.2 Energy is transferred from one store to another, and to another, and so on.

In Figure 10.2, stored chemical energy in the food is needed to help our bodies make a range of other chemicals. Some of these – like carbohydrates – are used to produce heat to maintain our body temperature and energy for movement through muscle activity. Having eaten a meal, the cyclist in Figure 10.2 is transferring the chemical energy stored in his body to movement energy. The movement is initially in the cyclist's legs and is then transferred to the machine (the bicycle). The cyclist is transferring additional energy by heating the surroundings. Friction in various parts of the bicycle will also result in energy being transferred from movement to heat and sound.

The dynamo or generator fitted to the bicycle's wheel transfers some of the movement energy of the wheel to electrical energy. The lamp then transfers energy as light radiation and by heating. As electrons flow in the dynamo–lamp circuit, the conducting wires will be heated.

Examples of other energy transfers are given in the questions at the end of the chapter.

CONSERVATION OF ENERGY

The principle of conservation of energy is a very important rule. It states that:

Energy is not created or destroyed in any process.

(It is just transferred from one store to another.)

We often hear about the energy crisis: as our demand for more energy increases our reserves of energy in the form of fuels like oil and gas are rapidly being used up. The principle of conservation of energy makes it seem as if there is no real problem – that energy can never run out. We need to understand what the principle really means.

Physicists believe that the amount of energy in the Universe is constant – energy can be transferred from one store to another but there is never any more or any less of it. This means we cannot use energy up. However, if we consider our little piece of the Universe, the problem becomes more obvious. As we make energy do useful things – for example, move a car – some of it will be transferred to heat. Some of it will be transferred by heating. Some of the thermal energy stored will be radiated away into space. This means the energy is not available for us to use any more.

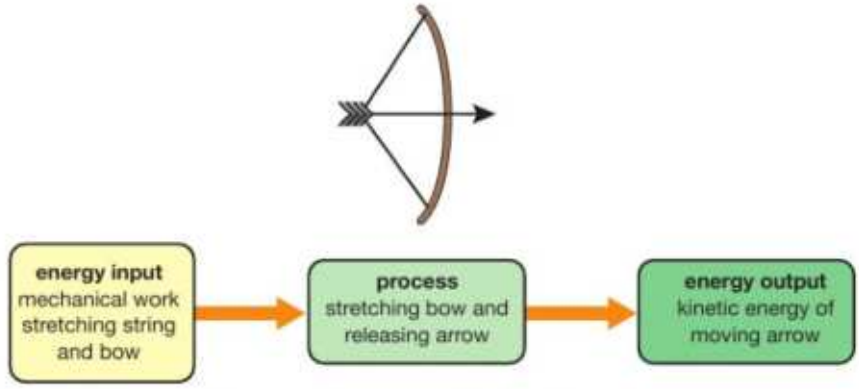
EXTENSION WORK

Even though the amount of energy in the Universe is constant, it is becoming more spread out and so less available for use. Some scientists think that all the energy in the Universe will eventually be transferred to heat and that everywhere in the Universe will end up at the same very low temperature. This possible 'end of the world' is sometimes referred to by the dramatic name of 'heat death'. If the Universe does end up this way, it is not expected to do so for some time yet, so carry on working for those exams!

This is just like a badly insulated house; if heat energy escapes, it is transferred away from the system we call our home, and is no longer available to keep us warm.

SANKEY DIAGRAMS

We use different ways to show how energy is transferred. Energy transfer diagrams show the energy input (contribution), the energy transfer process and the energy output (production). The system may be a very simple one with just one main energy transfer process taking place. An example of a simple system with its energy transfer diagram is shown in Figure 10.3.

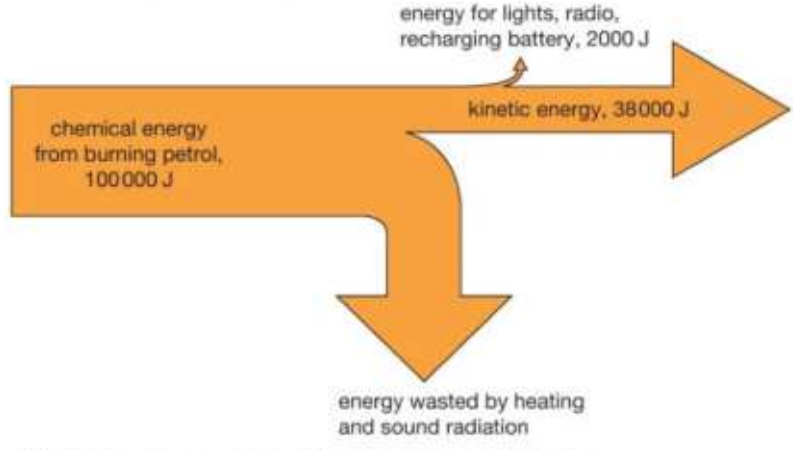


▲ Figure 10.3 Energy transfer diagram for an arrow being fired from a bow

Sankey diagrams are a simpler and clearer way of showing what happens to an energy input into a system. The energy flow is shown by arrows whose width is proportional to the amount of energy involved. Wide arrows show large energy flows, narrow arrows show small energy flows.

Figure 10.4 shows a Sankey diagram for a complex system – the energy flow for a car. Chemical energy in the form of petrol is the input to the car. The energy outputs from the car are:

- electrical energy (from the alternator) to drive lights, radio and so on, to charge the battery (transferred to chemical energy) and allow the car to switch on
- movement (kinetic) energy from the car engine
- wasted energy as electrical heating in wiring and lamp filaments, as frictional heating in various parts of the engine and alternator, and as noise.



▲ Figure 10.4 Sankey diagram showing the energy flow in a typical car

Here the 100 000 J of chemical energy input might be shown by an arrow 20 mm wide, so the 60 000 J of energy wasted (60% of the input) would then be shown by an arrow that is 12 mm wide (60% of 20 mm). It is difficult to draw the 2% arrow for the energy output to scale; it is enough to show it as very small.

EFFICIENCY

Whenever we are considering energy transfers, we have to remember that a proportion of the energy input is wasted. Remember that wasted means transferred into stores other than the useful store required. We would like our energy transfer systems to be perfect with all the output energy being in the store that we want. For example, not all the output energy for an electric lamp is light (the useful energy output), some of the output energy is thermal energy (not useful when what we want is light).

Real systems always have an unwanted energy output so can never have 100% efficiency.

The efficiency of an energy conversion system is defined as:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy output}} \times 100\%$$

HINT

If you calculate the efficiency of a system and get an answer bigger than 100% then you have put the numbers into the equation the wrong way round!

Efficiency does not have a unit because it is a ratio. Sometimes efficiency is shown as a **fraction** of the energy output that is in the wanted or useful store. In real energy transfers this fraction will always be less than 1 because some of the total output energy will be in an unwanted store.

EXAMPLE 1

A 60 W tungsten filament bulb uses 60 J of energy every second. It is 5% efficient. How much of the total energy output per second is useful light radiation?

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy output}} \times 100\%$$

$$5\% = \frac{\text{useful energy output}}{60\ \text{J}} \times 100\%$$

$$\frac{5}{100} = \frac{\text{useful energy output}}{60\ \text{J}}$$

So useful (light) energy from bulb $= \frac{5 \times 60\ \text{J}}{100} = 3\ \text{J}$ each second.

CHAPTER QUESTIONS

More questions on the need for energy can be found at the end of Unit 4 on page 616.

SKILLS CREATIVITY

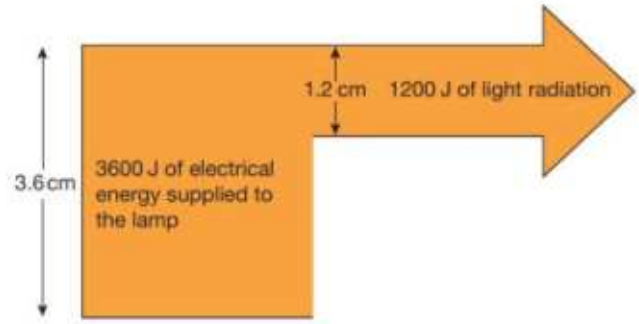
1 Describe the main energy transfers taking place in the following situations:

- a turning on a torch
- b lighting a candle
- c rubbing your hands to keep them warm
- d bouncing on a trampoline.

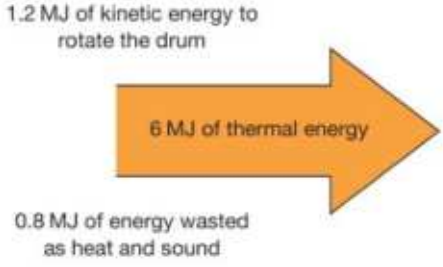
SKILLS INTERPRETATION, PROBLEM SOLVING

2 Copy and complete the following Sankey diagrams. Remember that the width of the arrows must be proportional to the amount of energy involved. This has been done for you in part a.

a for an electric lamp



b In a typical wash in a washing machine 1.2 MJ is transferred to the kinetic energy of the rotating drum, 6 MJ of energy is transferred to heat the water and 0.8 MJ is wasted as heat transferred to the surroundings and sound.



SKILLS INTERPRETATION

3 a Draw a Sankey diagram for the following situation. An electric kettle is used to heat some water. 350 kJ of energy are used to heat the water, 10 kJ raise the temperature of the kettle and 40 kJ escape to heat the surroundings.

SKILLS PROBLEM SOLVING

b Calculate the efficiency of the kettle.

4 A ball is dropped. It hits the ground with 10 J of kinetic energy and bounces with 4 J of kinetic energy.

a What happens to 6 J of the energy during the bounce?

SKILLS INTERPRETATION

b Draw a Sankey diagram for the energy flow that takes place during the bounce.

11 THERMAL ENERGY

This chapter is about the ways in which thermal (heat) energy is transferred from a hotter place to a cooler place.



▲ Figure 11.1 The transfer of thermal energy from place to place can be useful – for example, rising warm air creates 'thermals' that can carry this glider up to great heights.

LEARNING OBJECTIVES

- Describe how thermal energy transfer may take place by conduction, convection and radiation
- Explain the role of convection in everyday phenomena
- Explain how emission and absorption of radiation are related to surface and temperature
- Practical: investigate thermal energy transfer by conduction, convection and radiation
- Explain ways of reducing unwanted energy transfer, such as insulation

Thermal or heat energy is energy that is stored in 'hot' matter. We shall see that 'hot' is a relative term. There is a temperature called absolute zero that is the lowest possible temperature. Any matter that is above this temperature has some thermal energy. The kinetic energy of the minute particles that make up all matter produces the effect we call heat.

Thermal energy is transferred from a place that is hotter (that is, at a higher temperature) to one that is colder (at a lower temperature). In this chapter, we will look at the different ways in which thermal energy is transferred between places that have different temperatures.

CONDUCTION

Thermal **conduction** is the transfer of thermal (heat) energy through a substance by the vibration of the atoms within the substance. The substance itself does not move.

If you have ever cooked kebabs on a barbecue with metal skewers, as shown in Figure 11.2, you will have discovered conduction! The metal over the burning charcoal becomes hot and the heat energy is transferred along the skewer by conduction. In metals, this takes place quite rapidly and soon the handle end is almost as hot as the end over the fire. Metals are good thermal conductors. If you use skewers with wooden handles you can hold the wooden



▲ Figure 11.2 Metal skewers allow heat to be transferred to parts that are away from the heat.

Safety note: The metal rods will quickly get hot enough to burn the skin and will remain hot long after the heat is removed.

EXTENSION WORK

'Free electrons' are electrons that are not connected with any particular atom in the structure of a substance. Metals usually have huge numbers of free electrons per unit volume. Copper, for example, has about 10^{29} free electrons in each cubic metre. As these free electrons carry electric charge as well as energy, it is no coincidence that good thermal conductors are usually good conductors of electricity too.

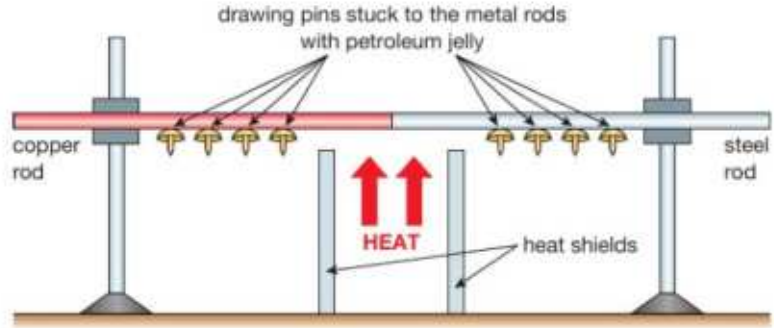
ends much more comfortably because wood does not conduct thermal energy very well. Wood is an example of a good thermal insulator.

The process of energy transfer by conduction is explained in terms of the behaviour of the tiny particles that make up all matter. In a hot part of a substance, like the part of the skewer over the hot charcoal, these particles have more kinetic energy. The more energetic particles transfer some of their kinetic energy store to particles near them mechanically. These therefore gain kinetic energy and then pass kinetic energy on to particles near to them. The energy transfer goes on throughout the substance. This process takes place in all materials.

In metals, the process takes place much more rapidly, because metals have free electrons that can move easily through the structure of the metal, making the transfer of energy happen faster.

ACTIVITY 1

▼ PRACTICAL: INVESTIGATE HOW WELL DIFFERENT METALS CONDUCT HEAT



▲ Figure 11.3 Experiment to show thermal conduction in different metals

Figure 11.3 demonstrates how thermal energy is transferred along the metal rods from the heated ends towards the cooler ends away from the heat source. As the thermal energy passes along the rods the petroleum jelly holding the drawing pins in place melts and they drop off in sequence. This experiment also shows that copper conducts thermal energy better than steel because the drawing pins attached to the copper rod drop off sooner than those attached to the steel rod. The rods should be the same diameter and the drawing pins placed at the same distances from the heat source for this to be a fair test.

CONVECTION

Convection is the transfer of thermal energy through fluids (liquids and gases) by the upward movement of warmer, less dense regions of fluid.

You may have seen a demonstration of convection currents in water, like the one shown in Figure 11.4. The water is heated just under the purple crystal and the crystal colours the water as it **dissolves**, which lets you see the movement in the water. The heated water expands and becomes less dense than the colder surrounding water, so it floats up to the top of the glass beaker. Colder water sinks to take its place, and is then heated too. At the top, the warm water starts to cool, becomes more dense again and will begin to sink, so a circulating current is set up in the water. This is called a convection current.

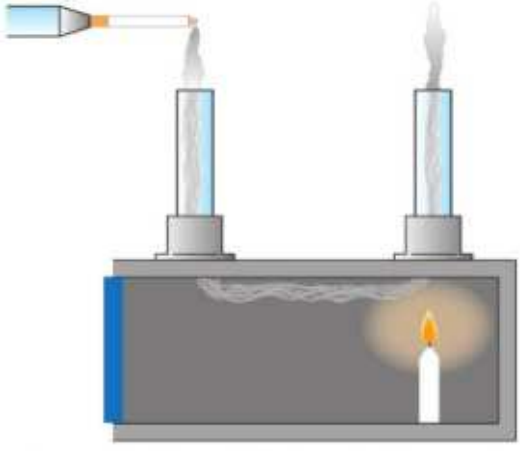
ACTIVITY 2

▼ PRACTICAL: INVESTIGATE CONVECTION CURRENTS IN WATER

Safety note: Avoid skin contact with the crystals and their solution.



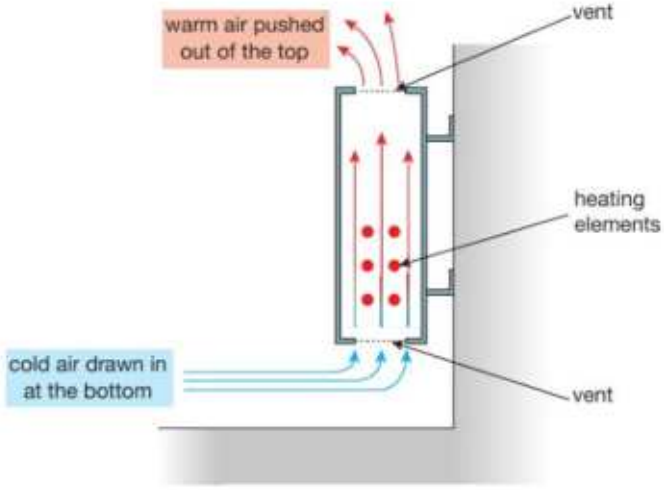
▲ Figure 11.4 Demonstration of convection currents, using a potassium manganate (VII) crystal in water



▲ Figure 11.5 Here, air warmed by the candle floats up the chimney on the right and colder air is drawn down the chimney on the left. Smoke from the burning candle shows up the circulation of the air.

EXTENSION WORK

Substances tend to expand when heated because the particles of which they are made have more kinetic energy. As they move around more, the average distance between the particles increases.



▲ Figure 11.6 A convector heater relies on the effects of convection.

Convection occurs in any fluid substance – that is, in things that can flow, such as liquids and gases. Convector heaters (Figure 11.6) heat air, which then floats out of the top of the heater to the top of the room. Cold air is drawn in at the bottom and this in turn is heated. In this way, thermal energy is eventually transferred to all parts of the room.

In many cooking ovens, the heating element is placed at the bottom of the oven. It heats the air near to it, and this air rises by convection. The top of the oven is generally warmer than the bottom, so you can cook foods at different temperatures. However many modern ovens are fan ovens, where hot air is blown into the oven and provides an even temperature throughout the oven.



▲ Figure 11.7 A diver wearing a wetsuit to keep warm in cold water

Air and water both allow thermal energy transfer to take place by convection as they are both fluids, but neither are good thermal conductors (they are insulators). This insulating property of both water and air is put to good use in situations where they are not able to circulate easily. For example, woollen clothing keeps you warm because air gets trapped in the fibres. The trapped air is heated by your body and forms a warm insulating layer that helps to stop you losing heat. In the same way, a wetsuit keeps a diver warm because a thin layer of water is trapped next to the diver's skin. (Figure 11.7)

Convection currents are responsible for many everyday events. One example is on-shore and off-shore breezes, also known as sea breezes and land breezes. These are explained in Figure 11.8.



▲ Figure 11.8 At night the air over the warmer sea floats up causing cooler air to flow towards sea. During the day the situation is reversed. In Unit 5 you will learn that some things heat up and cool down more easily than others.

Another example is convection currents within the very tall 'thunder' clouds that are responsible for the build-up of charge at the cloud base resulting in lightning strikes.

RADIATION

Thermal radiation is the transfer of energy by infrared (IR) waves.



▲ Figure 11.9 Thermal energy is transferred from a heater by radiation.

REMINDER

Remember that we are talking about thermal energy transfer – this is thermal radiation not nuclear radiation!

EXTENSION WORK

The reflector in an electric fire is a special shape, called a **parabola**. You can see parabolic reflectors in torches and radio telescopes, for example.

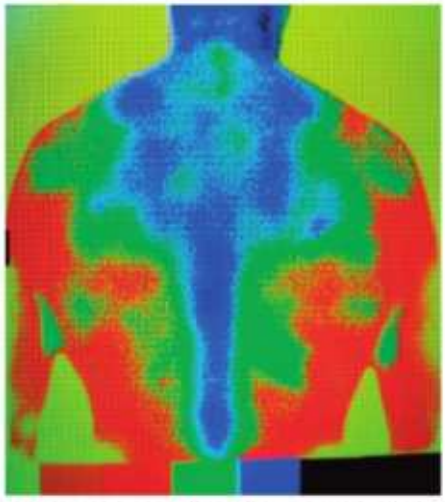
When you turn on a bathroom heater, as shown in Figure 11.9, you will feel the effect almost instantly. Neither conduction nor convection can explain how heat is getting from the hot part to your hands. Conduction does not occur that rapidly, even in good thermal conductors, and air is a poor thermal conductor. Convection results in heated air floating upwards on colder, denser air.

There are two things you should notice about this example.

1 The heat that you feel so quickly is travelling from the heater in a straight line.

2 The design of the bathroom heater includes a specially shaped, very shiny reflector, similar to the reflector behind a fluorescent light or in a torch.

In this example, thermal energy is travelling in the form of waves, like visible light. Heat waves are called infrared (IR) waves or IR radiation. The army and the emergency services use special cameras, called thermal imaging cameras, that can detect objects giving out IR waves. These cameras show images of people because of the thermal energy radiation from their bodies, even when there is not enough visible light to actually see them. Thermal imaging is also an important tool in the diagnosis of certain illnesses. (Figure 11.10)



▲ Figure 11.10 This is a thermal image of a patient showing areas of different temperatures.

IR waves are part of the same family of waves as light, radio waves, ultraviolet and so on, called the electromagnetic (EM) spectrum (see page 568). IR waves, therefore, have the same properties as all the other waves in the EM spectrum. In particular, IR can travel through a vacuum and does so at the speed of light (3×10^8 m/s).

It is important that thermal energy can travel in this way, without the need for matter, otherwise we would not receive heat, as well as light, from the Sun.

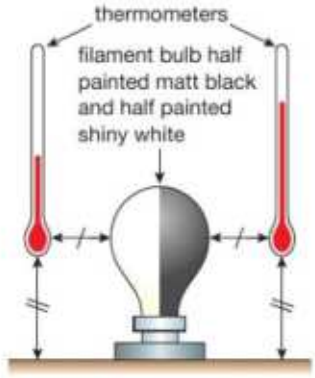
IR waves can also be reflected and absorbed by different materials, just like visible light. Highly polished, shiny surfaces are good reflectors of thermal radiation. White surfaces also reflect a lot of IR. Matt (not shiny) black and dark surfaces are poor reflectors or, to put it more positively, are good absorbers of thermal radiation. Figure 11.12 shows how this can be useful in everyday life.

ACTIVITY 3

▼ PRACTICAL: INVESTIGATE HOW WELL DIFFERENT SURFACES RADIATE HEAT

This experiment shows that matt black surfaces radiate heat better than shiny white surfaces.

Safety note: The bulb will quickly get hot enough to burn skin and ignite paper.



▲ Figure 11.11 Demonstrating that matt black surfaces radiate heat better than shiny white surfaces

Figure 11.11 shows the experiment. Put two identical (same type) thermometers on either side of a filament bulb that has been painted matt black on one side and shiny white on the other.

When you turn on the bulb you will notice that the temperature starts to rise more quickly on the thermometer facing the black side than on the other.

It is important that the thermometers are fixed at the same height and distance from the filament bulb.



▲ Figure 11.12 Shiny and white surfaces reflect thermal radiation, while matt black surfaces, like in the solar heating panels, absorb it.

a



b



▲ Figure 11.13 **a** A shiny kettle stays warmer longer. **b** The heat sink needs to be matt black to lose heat to the surroundings quickly, and so stop the transistor overheating.

If a surface is a good reflector of IR then it is a poor radiator of IR. This means that a hot object with a shiny surface will emit thermal energy in the form of IR than another object at the same temperature with a matt black surface. The kettle in Figure 11.13a has a shiny surface to reduce the rate of thermal energy loss. Heat sinks are used in electronic equipment to stop parts getting too hot. A heat sink is shown in Figure 11.13b. The transistor is fixed to the black metal heat sink and thermal energy is transferred from the transistor to the heat sink by conduction. The matt black surface radiates thermal energy well and the shape of the heat sink helps convection air currents to transfer thermal energy away from the heat sink.



▲ Figure 11.14 A tungsten filament bulb

The amount and type of the energy radiated by a hot object does not only depend on its surface texture (how it feels to the touch) and colour – it also depends on how hot it is. Not only does the amount of energy radiated per second increase significantly with temperature but the nature of the EM waves also changes. At a low temperature most of the radiated energy is in the form of infrared waves (invisible to the human eye). As the temperature of a metal object increases it starts to radiate in the visible spectrum as well. Things that do not burn will start to glow a dull red. As the temperature rises further the colour changes through the visible spectrum, for example, the tungsten filament glows white hot when it reaches ~3000 °C.

ENERGY-EFFICIENT HOUSES

We pay for the energy we use in our homes, schools and places of work. Heating is the main use of energy in our homes and – since most domestic heating systems work by burning fuels like coal, oil and gas – it is the main producer of carbon dioxide. (Even if electric heaters are used, most electrical energy is produced by burning fuels in power stations.) Carbon dioxide is a greenhouse gas and contributes to global warming. It is, therefore, very important that houses are energy efficient.

Energy efficiency means using as much as possible of the energy we produce for the desired purpose. So when we turn on the central heating, we want to keep the insides of our homes warm and not allow the heat (thermal energy) to escape. If no heat can escape from a house then we will only need to heat it until it reaches the desired temperature.

The key to energy-efficient housing is insulation. Houses must be designed to reduce the rate at which energy is transferred between the inside and the outside.

EXTENSION WORK

The greenhouse effect

Infrared waves from the Sun can pass through ordinary greenhouse glass. The IR waves heat up the ground, which re-radiates the heat. However, the re-radiated heat is in the form of IR waves with much longer wavelengths. The longer wavelength IR waves cannot pass through glass, so they are trapped inside the greenhouse. Carbon dioxide in our atmosphere acts in the same way as the glass in a greenhouse. It traps the Sun's heat.

EXTENSION WORK

In cooler climates it is more appropriate to concentrate on keeping heat (thermal energy) in, rather than thinking about how to keep it out.

EXTENSION WORK

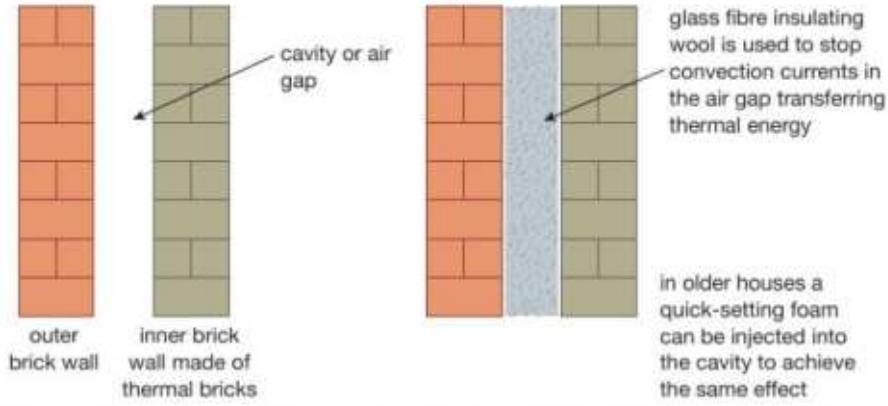
It is worth remembering that, in some countries, the problem is not keeping warm but keeping cool. Keeping cool also requires energy to run air-conditioning units, fans and other cooling devices. An energy-efficient house in a hot climate would stay cool by reducing the rate at which heat (thermal energy) entered the house.

HOW HEAT IS LOST

To insulate a house effectively we must look at all the ways in which thermal energy can escape. Conduction is the main way thermal energy is transferred between the inside of a building and the outside. Next we need to consider the places where conduction occurs: the walls, the windows (and doors) and the roof.

REMINDER

Energy lost here means energy transferred to unwanted energy stores. In the case of heating a house the wanted energy store will be the air in the rooms. An unwanted energy store in this example would be the outside environment.



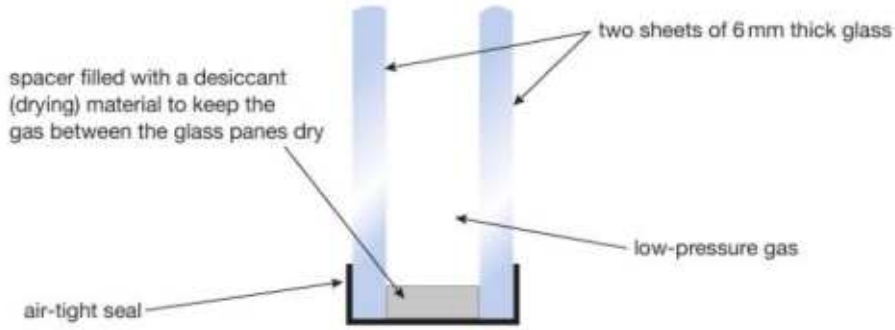
▲ Figure 11.15 Two-layered wall construction, with the gap filled with insulation panels, helps to reduce thermal energy loss by conduction, convection and even radiation.

Thermal energy loss by conduction through the walls can be reduced by using building materials that are good insulators. However, the materials used for building must also have other suitable properties like strength, durability and availability at a sensible price. For walls, bricks are a common building material.

Figure 11.15 shows the typical construction of a modern house in the UK built to follow the current energy efficiency regulations.

As you can see, the wall is made with layers of different materials. The outer layer is made with bricks – these have quite good insulating properties, are strong and will survive bad weather conditions. The inner layer is built with thermal bricks with very good insulation properties – they are also light, relatively cheap and quick to work with. The two layers of brick are separated by an excellent thermal insulator in the form of an air cavity or gap.

The walls also stop thermal energy being lost by convection. The cavity or gap between the two walls is wide enough for convection currents to circulate. This means thermal energy is circulated from the warmer surface of one wall to the colder surface of the other. To stop convection currents, the gap in modern houses is filled with insulating panels made of glass fibre matting. This is a lightweight, poor conductor that traps lots of air. The panels are usually surfaced with thin aluminium foil. This highly reflective surface reflects thermal energy in the form of infrared radiation.



▲ Figure 11.16 Double glazing helps to stop thermal energy escaping from the home.

Figure 11.16 shows a cross-section of a typical double-glazed window, as used in modern houses. Glass is a poor thermal conductor but is used in thin layers. To improve the insulating properties, two layers of glass are used to trap a layer of air. The thickness of this layer is important. If it is too thin then the insulation effect is reduced, but if it is too thick then convection currents will be able to circulate and carry heat from the hotter surface to the colder one. In very cold countries triple glazing is used. Modern double glazing uses special glass to increase the greenhouse effect (thermal radiation from the Sun can get in but radiation from inside the house is mainly reflected back again).

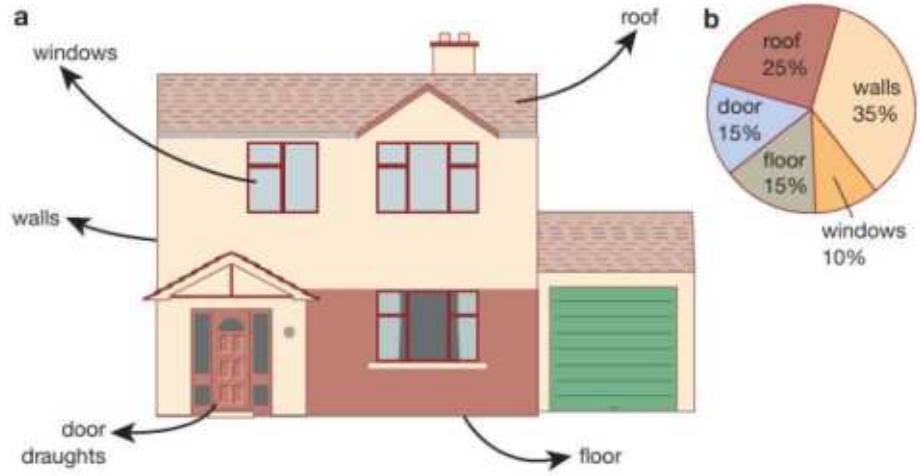
Roof insulation in modern houses uses similar panels to those used in the wall cavities, trapping a thick layer of air. This takes advantage of the poor conducting property of air, while also preventing convection currents circulating. Again, reflective foil is used to reduce thermal energy loss by radiation. Figure 11.17 shows houses built before loft insulation was a compulsory building regulation. In some, the owners have installed loft insulation – you should be able to identify which!



▲ Figure 11.17 Loft insulation makes a big difference to heat loss through the roof.

There are other things that can be done to improve the energy efficiency of houses that do not relate directly to the mechanisms of thermal energy transfer discussed in this chapter. For example, thermostats and computer control systems for central heating can further reduce the heating needs of a house. They stop rooms being heated too much by switching off the heat when a certain temperature is reached. Another important energy-saving measure is the reduction or elimination of draughts (air currents) from poorly fitting doors and windows.

With your understanding of how thermal energy travels you can save your family money, keep warm and reduce global warming.



▲ Figure 11.18 **a** How thermal energy can be lost from the home; **b** Percentage of energy lost in different ways

INSULATING PEOPLE AND ANIMALS

Earlier in this chapter we saw a picture of a fire fighter in protective clothing designed to reduce the amount of heat getting to their bodies (Figure 11.12). Sometimes we have the opposite problem and want to keep warm. The obvious method of cutting down heat loss from the body is to wear clothes. Clothes that trap air around the body provide insulation because trapped air cannot circulate and is a very poor conductor. A large proportion of body heat (thermal energy) is lost from the head, so hats are the human equivalent of loft insulation.

Wind can cause rapid thermal energy loss from the body. It does this by forced convection – that is, making air circulate close to the body surface. It may also cause sweat to **evaporate** from the skin more quickly, causing rapid cooling. (The purpose of sweat is to help the body to lose thermal energy by evaporation, but, if it happens because of strong wind on a cold day, the effect can be life threatening.) These cooling effects of wind contribute to what is called the wind-chill factor. To reduce the wind-chill effect, a piece of wind-proof outer clothing should be worn.

When people do lose thermal energy at too great a rate they may become hypothermic, which means their body temperature starts to fall. If the heat loss is not significantly reduced the condition is potentially fatal. When people are rescued from mountains suffering from the effects of cold they are usually wrapped in thin, highly reflective blankets. The interior reflective surface reflects thermal energy back to their bodies while the outer reflective surface is a poor radiator of thermal energy. Marathon runners are often covered in these blankets at the end of the race to keep them warm when their energy reserves are low.



▲ Figure 11.19 Penguins stand close together for warmth.

Animals keep warm in different ways. You may have noticed birds fluffing up their feathers on cold days in winter. This increases the thickness of the trapped air layer around their bodies, so reducing thermal energy loss by conduction. Some birds, like penguins, will move close together for warmth (Figure 11.19). Other animals will curl into small balls. This cuts down thermal energy loss by making the surface area of their bodies exposed to the cold as small as possible.

CHAPTER QUESTIONS

More questions on thermal energy can be found at the end of Unit 4 on page 616.

SKILLS CREATIVITY, REASONING

1 Explain the following observations, referring to the appropriate process of thermal energy transfer in each case.

a Two cups of tea are poured at the same time. They are left for ten minutes. One of the cups has a metal teaspoon left in it. The tea in this cup is cooler than the tea in the other cup at the end of the ten-minute period.

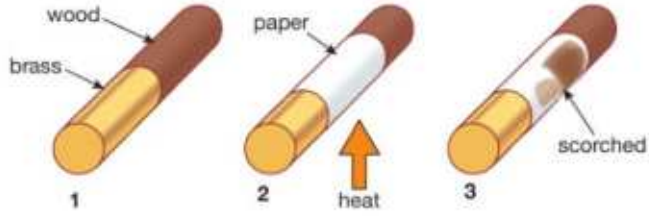
b Two fresh cups of tea are poured. (The others had gone cold!) A thin plastic lid is placed on top of one of the cups. The tea in this cup keeps hot for longer.

SKILLS REASONING

2 a Kettles heated on stoves used to be made of copper. Was this a good choice?

b Copper kettles were usually kept highly polished (shiny). If it is not polished, copper turns matt and eventually blackens as it reacts with oxygen in the air. Apart from making the kettle look nice, what is a good physics reason for keeping a copper kettle polished?

3 The diagrams below show a physics demonstration about thermal conduction.



A cylinder is made from a piece of brass fitted to a piece of wood. A piece of paper is glued around the middle. The paper is then heated over a Bunsen burner flame. After a while one end of the paper is noticeably more burned than the other. Explain why this happens.

SKILLS CREATIVITY, REASONING

4 There are two bench seats in a park, one made of metal, the other made of wood. The metal seat feels much colder to sit on than the wooden one. A student says that it is because the metal seat is at a lower temperature than the wooden one. Explain why this explanation is incorrect, and give a correct explanation of why the metal seat seems colder than the wooden one.

SKILLS REASONING

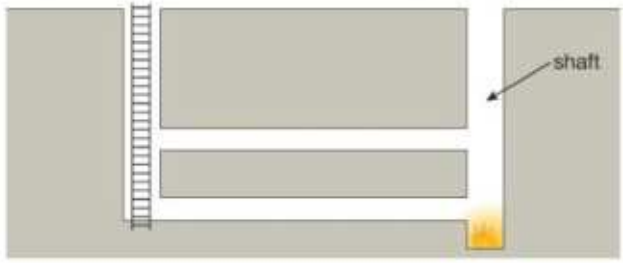
5 a Why is the heating element (part) in an electric kettle positioned very close to the bottom of the kettle?

b Where would you expect the cooling element to be placed in a freezer? Give a reason for your answer.

SKILLS CREATIVITY, REASONING

6 One model of a well-known brand of computer does not use a fan to keep the electronic circuits inside it cool, unlike other PCs. A student noticed that the ventilation (air) slots on most other PCs are positioned on the side, but the slots are on the top and bottom surfaces of this computer. The designer has applied physics to the problem of keeping the computer cool. Explain why the new computer does not need a fan.

7 The diagram below shows how Roman mines used to be ventilated.



The mine system had a shaft with a fire lit at the bottom. Explain how this kept the air in the mine system fresh.

SKILLS EXECUTIVE FUNCTION

8 a Describe an experiment to show that matt black surfaces absorb thermal radiation better than shiny metallic surfaces. Your description should include details of the apparatus; you may use a clearly labelled sketch diagram in your answer.

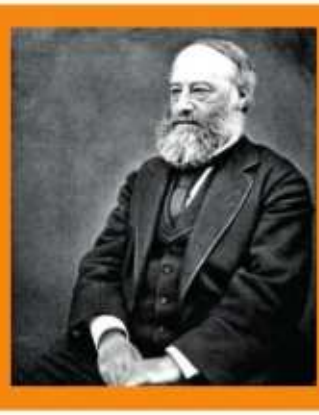
b State what measurements you would take.

c Explain how you would make sure your investigation is fair.

d How would your results show that the idea that a matt black surface absorbs thermal radiation better than a shiny metallic surface is correct?

12 WORK AND POWER

Work is calculated by multiplying the force applied by the distance through which the force moves – the bigger the force, or the longer the distance through which it moves, the more work is done. Work always involves an energy transfer. Power is the rate at which energy is transferred, and efficiency is a measure of how much of the input energy to a system is converted to useful output energy. In this chapter you will learn how to calculate the work done in a system and its power as energy is transferred.



▶ Figure 12.1 James Joule (1818–1889) was the son of a wealthy Manchester brewer. He was tutored by James Dalton and carried out scientific research in his own laboratory, built in the basement of his father's home.

LEARNING OBJECTIVES

- Know and use the relationship between work done, force and distance moved in the direction of the force:

  work done = force × distance moved

  $W = F \times d$
- Know that work done is equal to energy transferred
- Know and use the relationship between gravitational potential energy, mass, gravitational field strength and height:

  gravitational potential energy = mass × gravitational field strength × height

  $GPE = m \times g \times h$
- Know and use the relationship:

  kinetic energy = $\frac{1}{2}$ × mass × speed squared

  $KE = \frac{1}{2} \times m \times v^2$
- Understand how conservation of energy produces a link between gravitational potential energy, kinetic energy and work
- Describe power as the rate of transfer of energy or the rate of doing work
- Use the relationship between power, work done (energy transferred) and time taken:

  $$\text{power} = \frac{\text{work done}}{\text{time taken}}$$

  $$P = \frac{W}{t}$$

The unit of energy is named after James Joule. It was Joule who realised that heat was a store of energy. He showed that kinetic energy could be transferred to heat. At that time heat was measured in **calories**.

ENERGY AND WORK

Energy is the ability to do work.

This statement tells us what energy does rather than what energy is. We know that energy is found in a wide variety of different stores but we are really interested in what energy can do – the answer is that energy does work.

We need to define work in a way that is measurable. Some types of work are not easy to calculate the value of. Mechanical work, like lifting heavy objects, is easy to measure: if you lift a heavier object, you do more work; if you lift an

object through a greater distance, again, you do more work. The definition of work in physics is:

work done, W (joules) = force, F (newtons) × distance moved, d (metres)

$$W = F \times d$$

If the force is measured in newtons and the distance through which the force is applied is measured in metres then the work done will be in joules.

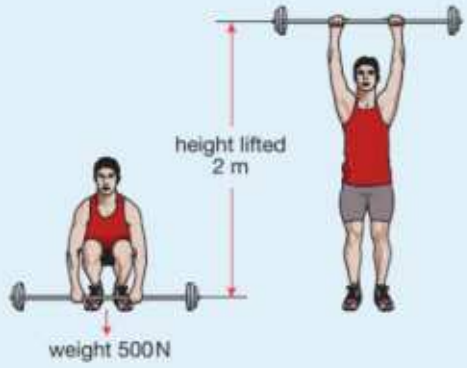
Work done is equal to the amount of energy transferred.

1 J of work done is transferred when a force of 1 N is applied through a distance of 1 m in the direction of the force.

EXAMPLE 1

Figure 12.2 shows a weightlifter raising an object that weighs 500 N through a distance of 2 m. To calculate the work done we use:

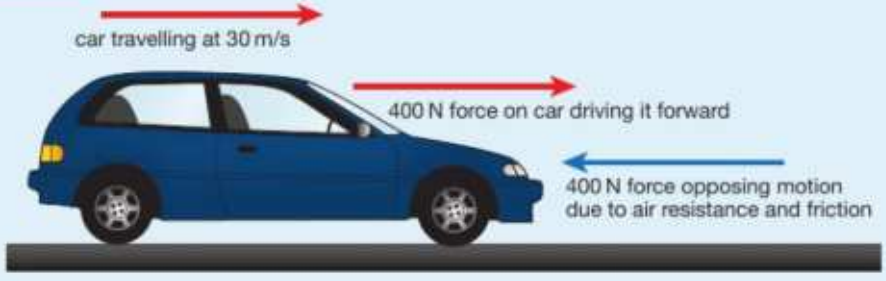
$W = F \times d$
$= 500\ \text{N} \times 2\ \text{m}$
$= 1000\ \text{J}$



▲ Figure 12.2 Doing work by lifting a weight

This work done on the weight has increased its energy. This is explained in the section on gravitational potential energy (page 610).

EXAMPLE 2



▲ Figure 12.3 A car travelling at a constant speed doing work

In the example shown in Figure 12.3 the force acting on the car is not accelerating it – instead, it is being used to balance the forces opposing its movement. The resultant force on the car is zero, so it keeps moving in a straight line at constant speed. To work out the work done on the car in one second we substitute the force required, 400 N, and the distance through which it acts in one second, 30 m, in the equation:

$W = F \times d$
$= 400\ \text{N} \times 30\ \text{m}$
$= 12\,000\ \text{J or } 12\ \text{kJ}$

GRAVITATIONAL POTENTIAL ENERGY (GPE)

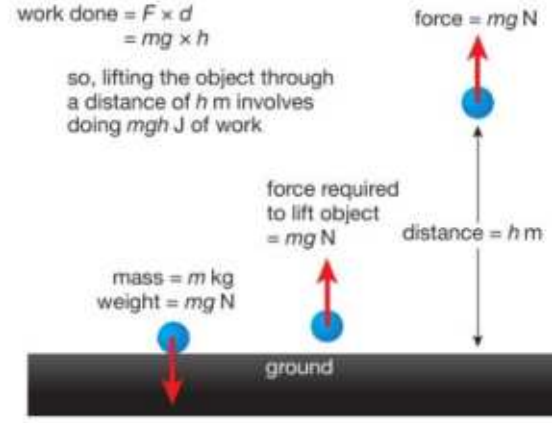
The gravitational potential energy of an object that has been raised to a height, *h*, above the ground is given by:

gravitational potential energy, *GPE* (joules) = mass of object, *m* (kilograms) × gravitational field strength, *g* (newtons per kilogram) × height, *h* (metres)

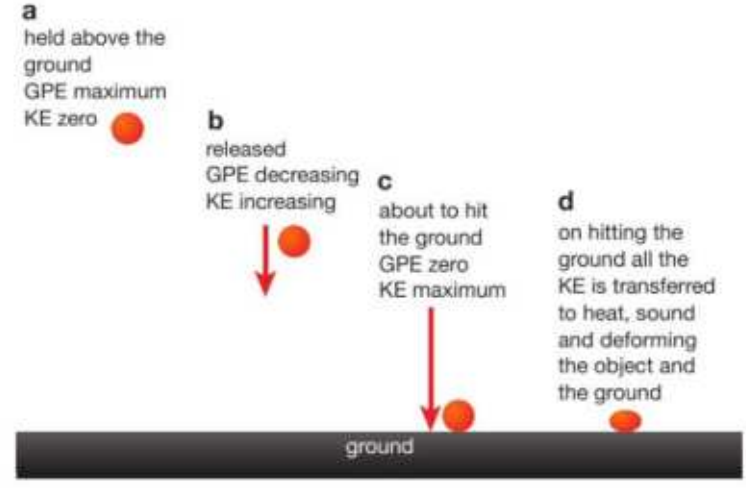
$$GPE = m \times g \times h$$

The change in the GPE of an object will be an increase if we apply a force on it in the opposite direction to the pull of gravity – that is, if we lift it off the ground. When an object falls it loses GPE. To keep things simple, we usually assume that an object has no GPE before we do work on it.

In the weight-lifting example given on page 609, the weightlifter has used some chemical energy to do the work. We know that energy is conserved so what has happened to the chemical energy that the weightlifter used? Some has been transferred to heat in the weightlifter's body. The remainder has been transferred to the weight because he has increased its height in the gravitational field of the Earth. The energy that the weight has gained is called gravitational potential energy or GPE.



▲ Figure 12.4 The work done to lift an object is equal to the GPE the object has at its new height.



▲ Figure 12.5 When a raised object falls, its gravitational potential energy is transferred first to kinetic energy and then to heat and sound.

KEY POINT

Kinetic energy (KE) is the energy stored by moving objects.

In Figure 12.5, we can see the GPE stored by the weight is being transferred to other stores as the weight falls. The weight accelerates because of the force of gravity acting on it, so it gains kinetic energy. When it reaches the ground all the initial GPE is transferred to kinetic energy. When it hits the ground all the movement energy is then transferred to other stores, mainly heat and sound.

REMINDER

Gravitational field strength is the force acting per kilogram on a mass in a gravitational field. The gravitational field strength, g, on the surface of the Earth is approximately 10 N/kg. Since the weight of an object is mg, increase in GPE is a special version of the equation $W = F \times d$, with $F = mg$ and $d = h$.

KINETIC ENERGY, KE

The kinetic energy of a moving object is calculated using the equation:

kinetic energy, KE (joules) = mass, m (kilograms) × speed squared, v^2 (metres squared per seconds squared)

$$KE = \frac{1}{2}mv^2$$

EXTENSION WORK

In Chapter 1 we saw the equation of uniformly accelerated motion:

$v^2 = u^2 + 2as$

This equation allows us to work out the final velocity, v, of an object that has a uniform acceleration, a, and that has accelerated through a distance, s, starting with an initial velocity of u.

If we drop an object from rest its initial velocity, $u = 0$, its acceleration is g m/s^2 and the distance that it falls is usually represented by h, so the equation becomes

$v^2 = 2gh$

Multiplying both sides of the equation by m, the mass of the object, gives:

$mv^2 = 2mgh$ which can be rearranged as $\frac{1}{2}mv^2 = mgh$

showing that the gain in KE of the object is equal to its loss of GPE.



▲ Figure 12.6 Meteors burn up on entering our atmosphere – we see them as 'shooting stars'.

We see that the amount of kinetic energy possessed by a moving object depends on its speed and its mass. As the Earth travels through space, orbiting the Sun, it runs the risk of colliding with chunks of matter that are drawn into the gravitational field of the Solar System. In fact, this is very common. If you have ever seen a shooting star – or, to give it its proper name, a meteor – you have seen the line of light produced as a small piece of space debris (waste) burns up on entering our atmosphere. This is an example of kinetic energy being transferred to heat and light by the friction produced between the air and the object passing through it.

EXTENSION WORK

The meteorite that caused the Arizona crater is thought to have hit the Earth travelling at 11 000 m/s and to have had a mass of 109 kilograms. It hit the ground with an energy equivalent to a 15 megaton hydrogen bomb, 1000 times greater than the atomic bomb dropped on Hiroshima at the end of the Second World War.



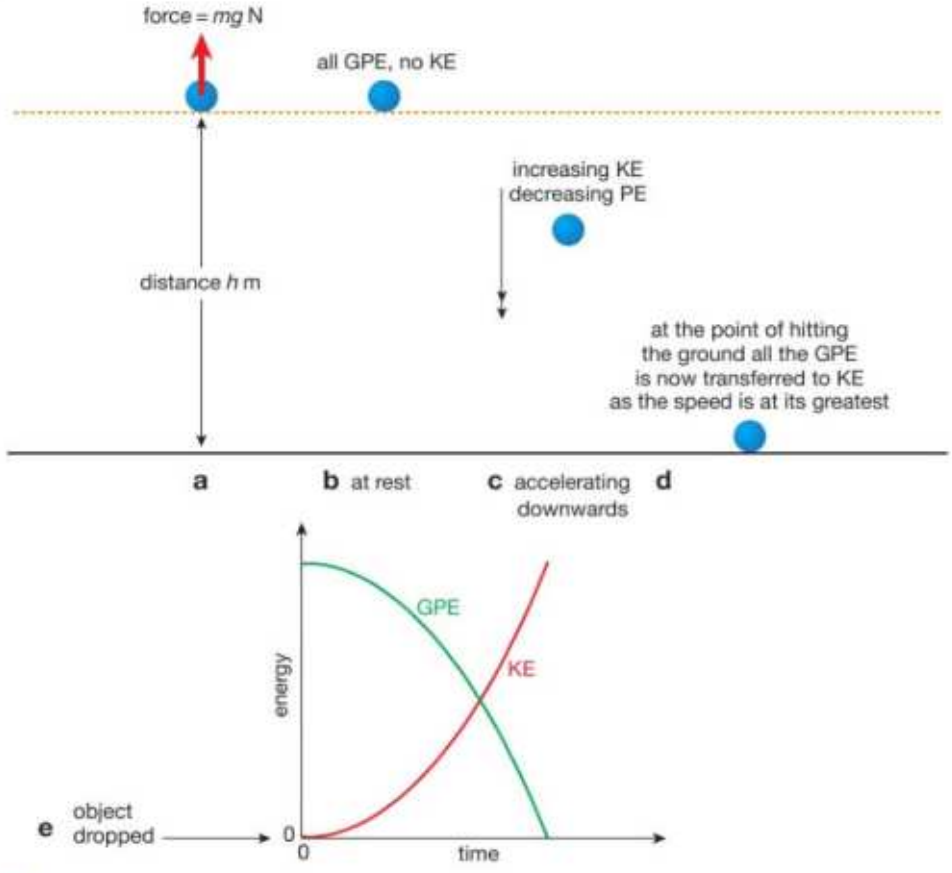
▲ Figure 12.7 This crater was created when a meteorite collided with Earth in Arizona.

EXAMPLE 3

Calculate the kinetic energy carried by a meteorite of mass 500 kg (less than that of an average-sized car) hitting the Earth at a speed of 1000 m/s.

$$KE = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2} \times 500\ \text{kg} \times (1000\ \text{m/s})^2$$
$$= 250\,000\,000\ \text{J (or 250 MJ)}$$

CALCULATIONS USING WORK, GPE AND KE



▲ Figure 12.8 GPE and KE of a falling object: **a** doing work to lift an object; **b** all GPE; **c** GPE transferring to KE during fall; **d** all KE at end of fall; **e** graph showing relationship between GPE and KE as the object falls

Work transfers energy to an object: $W = Fd$. An object of mass, m, weighs ($m \times g$) newtons so the force, F, needed to lift it is mg (Figure 12.8). If we raise the object through a distance h, the work done on the object is $mg \times h$. This is also the gain in GPE.

When the object is released, it falls – it loses GPE, but gains speed and so gains KE. At the end of the fall, all the initial GPE of the stationary (not moving) object has been transferred to the KE of the moving object. The graphs in Figure 12.8 show how the GPE of the object is changing into KE as it falls. The sum of the two graphs is always the same. Energy is conserved, so the loss of GPE is equal to the gain in KE.

$$\text{work done lifting object} = \text{gain in GPE} = \text{gain in KE of the object just before hitting the ground}$$

EXAMPLE 4



▲ Figure 12.9 A rollercoaster ride

In a rollercoaster ride the truck falls through a height of 17 m. Calculate the truck's speed at the bottom of this fall. (Take g = 10 N/kg)

If we assume that all the GPE of the truck at the top of the ride is transferred to KE at the bottom we can use the equation:

$$GPE = KE$$

$$mgh = \tfrac{1}{2}mv^2$$

The mass, m, of the truck appears on both sides of the equation, so it cancels out:

$$gh = \tfrac{1}{2}v^2$$

Substituting h = 17 m and g = 10 N/kg:

$$17\text{ m} \times 10\text{ N/kg} = \tfrac{1}{2}v^2$$

$$v^2 = 2 \times 17\text{ m} \times 10\text{ N/kg}$$

$$v = \sqrt{(2 \times 17\text{ m} \times 10\text{ N/kg})}$$

$$= 18.44\text{ m/s (about 66 kph)}$$

Some of the GPE the truck had at the start will be transferred to heat and sound, so the speed at the bottom of the fall will be a little slower than this.





▲ Figure 12.10 **a** James Watt (1736–1819) was a Scottish engineer who improved the performance of the steam engine and can be said to have started the Industrial Revolution – the beginning of the machine age. **b** A model of a steam engine that transfers the heat energy of steam to movement. Watt's engines were used to pump water out of mines.

POWER

Power is the rate of transfer of energy or the rate of doing work.

James Watt (Figure 12.10a) is remembered as the inventor of the steam engine and is said to have been inspired by watching the lid on a kettle being forced up by the pressure of the steam forming inside. Neither story is accurate, but what is true is that Watt, working in partnership with Matthew Boulton, developed improvements to the steam engine that made it a commercial product and completely changed industry and transport.

The SI unit of power is named in honour of James Watt. The watt (W) is the rate of transfer or conversion of energy of one joule per second (1 J/s).

$$\text{power, } P\text{ (watts)} = \frac{\text{work done, } W\text{ (joules)}}{\text{time taken, } t\text{ (seconds)}}$$

$$P = \frac{W}{t}$$

ACTIVITY 4

▼ PRACTICAL: INVESTIGATE YOUR POWER OUTPUT

You may have done a simple experiment involving running upstairs to measure your output power. You do work as you raise your GPE, and to find your power output in watts you divide the work done by the time taken. The experiment is shown in Figure 12.11. Notice that calculating the work you do against gravity using force × distance works just as well as using the equation for *GPE* (mass × gravitational field strength × height).

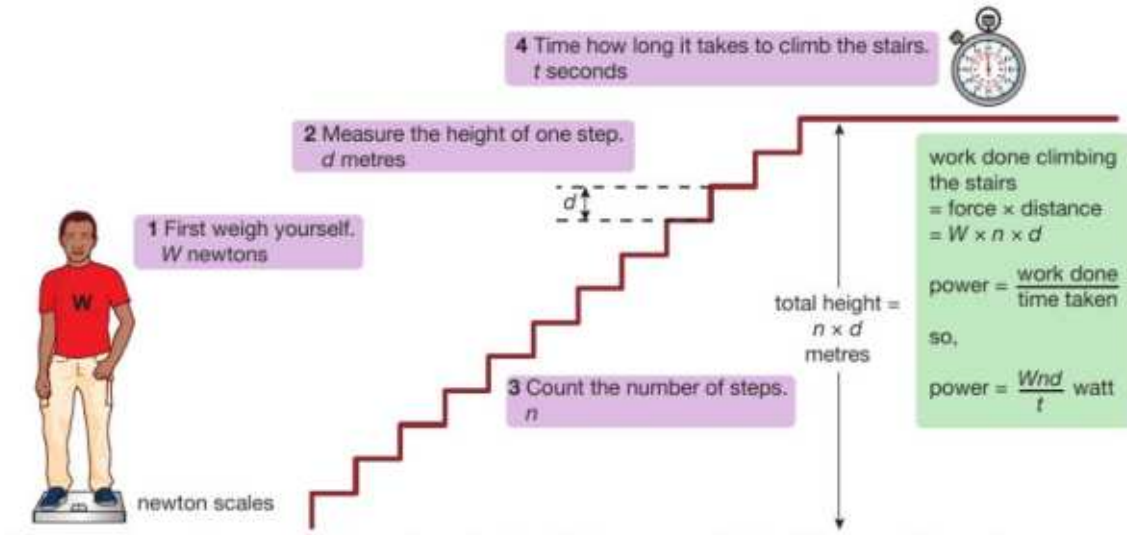


Figure 12.11 An experiment to measure your output power

If you don't have scales measuring in newtons, simply multiply your mass in kg by 10 to convert to newtons.

Safety note: Wear suitable footwear and only allow one person at a time on the staircase. Ensure the stairs are dry, in good condition and free of any obstacles.

A more convenient way of raising your GPE and getting to a higher floor in a building is to take a lift. The lift will transfer its energy input, usually electrical, to kinetic energy and then, if you are going up, to GPE. As usual, unwanted energy transfers are inevitable – sound and heat will be produced. If we know the weight of the lift and its contents and the height through which it moves, we can calculate the work done in the usual way. If we measure the time that the lift journey takes we can then calculate the power output of the lift motor. (Strictly this will be the useful power output – it will not take account of the wasted power due to unwanted energy transfers.)

EXAMPLE 5

If a lift and passengers have a combined weight of 4000 N and the lift moves upwards with an average speed of 3 m/s then what is the useful power output of the lift motor?

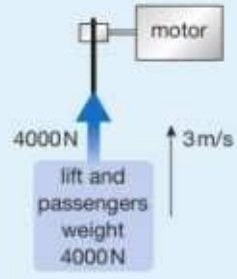


Figure 16.12

To keep the lift moving upwards at a steady speed, the lift motor must provide an upward force to balance the weight of the lift. This is 4000 N. In each second, this force is applied through a vertical distance of 3 m, so:

work done per second = 4000 N × 3 m/s

= 12 000 J/s

= 12 000 W

CHAPTER QUESTIONS

More questions on work, power and efficiency can be found at the end of Unit 4 on page 616.

In the questions below, where necessary, take the strength of the Earth's gravity to be 10 N/kg.

SKILLS CRITICAL THINKING

1 James Joule showed that heat is a store of energy. He did this by showing that heat can be produced by using mechanical energy.

a Give an example of a process in which kinetic energy is transferred to heat.

b Describe how heat energy can be transferred to either kinetic energy or gravitational potential energy.

2 a State the SI unit of work.

b Define the unit of work.

SKILLS PROBLEM SOLVING

c How much work is done in each of the following situations?

i A bag of six apples each weighing 1 N is lifted through 80 cm.

ii A rocket with a thrust of 100 kN travels to a height of 200 m.

iii A weightlifter raises a mass of 60 kg through a height of 2.8 m.

iv A lift of mass 200 kg lifts three people of mass 50 kg each through a distance of 45 m.

3 Water from a **hydroelectric power** station reservoir is taken from a reservoir (artificial lake) at a height of 800 m above sea level to turbines (engines) in the power station itself. The power station is at sea level. The reservoir holds 200 million (2×10^8) litres of water. If a litre of water has a mass of 1 kg, how much gravitational potential energy is stored in the water in the reservoir?

SKILLS CRITICAL THINKING

4 a State how to calculate the kinetic energy stored by a moving object.

SKILLS PROBLEM SOLVING

b Work out the kinetic energy of the following:

i a man of mass 80 kg running at 9 m/s

ii an air rifle pellet of mass 0.2 g travelling at 50 m/s

iii a ball of mass 60 g travelling at 24 m/s.

5 A catapult fires a stone of mass 0.04 kg vertically upwards. If the stone has an initial kinetic energy of 48 J, how high will it travel before it starts to fall back to the ground?

6 If a coin is dropped from a height of 80 m, how fast will it be travelling when it hits the ground? State any assumptions you may need to make.

SKILLS CRITICAL THINKING

7 Define power and state its unit.

SKILLS PROBLEM SOLVING

8 A person with a mass of 40 kg runs upstairs in 12 s. The stairs have 20 steps and the height of each step is 20 cm.

a How much does the person weigh, in newtons?

b What is the total height that the person has climbed?

c Calculate how much work is done in climbing the stairs.

d What is the power output of the person running up the stairs?

9 A drag car, of mass 500 kg, accelerates from rest to a speed of 144 km/h in 5 s.

a What is its final speed in:

i m/h (metres per hour)

ii m/s?

b What is the increase in KE of the drag car?

c What is the average power developed by the drag car's engine?

UNIT QUESTIONS

SKILLS PROBLEM SOLVING 6th 1

a A fluorescent lamp is 25% efficient. Choose the statement that correctly describes how the lamp performs.

A the lamp only works for a quarter of the time

B 25% of the energy transferred to the lamp is wasted

C the lamp does not work properly

D 25% of the energy supplied to the lamp is transferred to light **(1)**

SKILLS CRITICAL THINKING 5th

b A car uses energy stored in chemical form in petrol. When the engine is running this energy is transferred to other types of stored energy. Which of the following energy stores is useful?

A noise

B heat

C movement

D hot exhaust gases **(1)**

c Which of the following materials is a good thermal conductor?

A glass

B aluminium

C air

D water **(1)**

6th

d Which of the following statements about thermal radiation is false?

A It cannot travel through glass.

B It can travel through a vacuum.

C It travels at the speed of light.

D It is absorbed by black objects better than shiny ones. **(1)**

SKILLS PROBLEM SOLVING 7th

e Four students, A, B, C and D, measure their power output by running upstairs and timing how long it takes. Which of the four students has the greatest power output?

A mass of 50 kg, takes 20 s to gain a height of 10 m

B mass of 40 kg, takes 30 s to gain a height of 15 m

C mass of 45 kg, takes 10 s to gain a height of 5 m

D mass of 55 kg, takes 25 s to gain a height of 15 m **(1)**

(Total 5 marks)

SKILLS PROBLEM SOLVING

2 An electric motor is used to raise a load that weighs 800 N through a distance of 30 m.

a How much work does it do in raising the load? **(3)**

b Calculate the power output of the motor if it takes 16 s to raise the load. **(2)**

c The motor is 75% efficient.

SKILLS CRITICAL THINKING

i Explain what this means. **(2)**

SKILLS PROBLEM SOLVING

ii Calculate the electrical power that must be supplied to the motor to raise this load in the time stated. Give your answer in kW. **(2)**

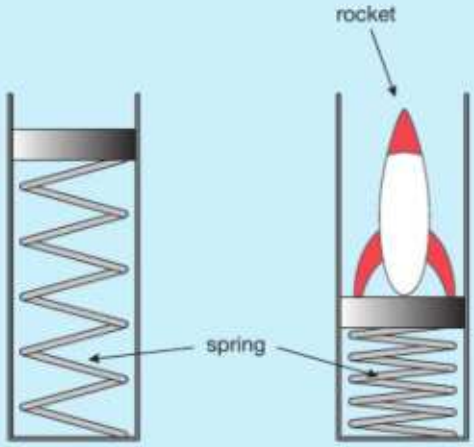
SKILLS INTERPRETATION

d Draw a labelled Sankey diagram to represent the energy transfers that take place as the motor raises the load. **(3)**

(Total 12 marks)

SKILLS ANALYSIS, REASONING

3 The diagram shows a toy rocket launcher that uses a spring in a tube.



a Here are statements that describe the events leading to the launch of the toy rocket:

1 spring released

2 rocket leaves launcher

3 rocket gains kinetic energy

4 spring stores elastic potential energy

5 child does work squashing the spring

6 spring transfers stored energy to rocket

Choose from the following list the letter that describes the events in the order that they must happen. **(1)**

A 156324 **B** 541632 **C** 154632 **D** 541623

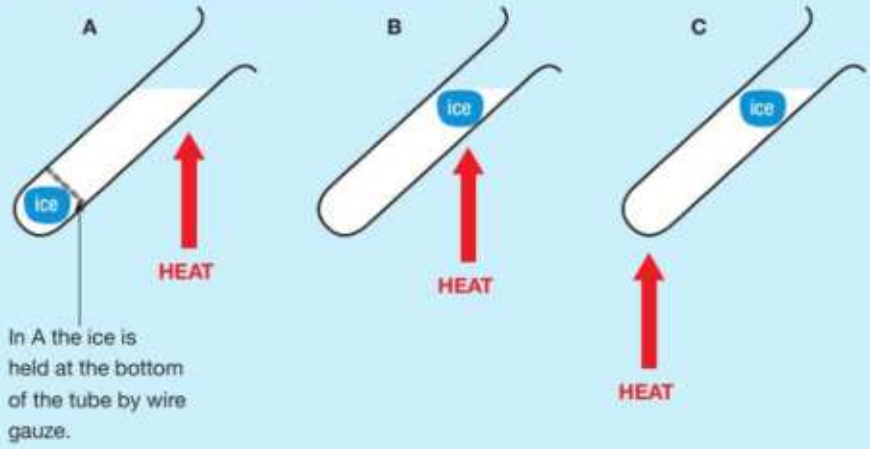
SKILLS CRITICAL THINKING

b Describe the energy transfers that take place after the rocket leaves the launcher, up to and including when it hits the ground. **(4)**

(Total 5 marks)

SKILLS EXECUTIVE FUNCTION

4 A student wants to show that water is a poor conductor of heat. The diagram below shows the investigation he sets up.



The student measures how long it takes for each piece of ice in the water to melt. The results will help him to show whether or not water is a poor conductor.

a State anything the student should do to make sure this is a fair test. **(3)**

SKILLS REASONING

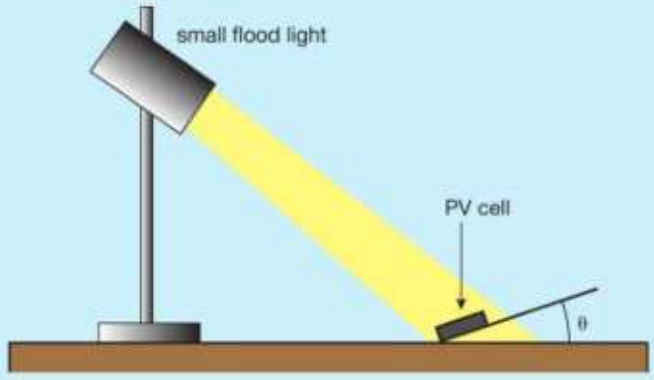
SKILLS EXECUTIVE FUNCTION

b i Assuming that this is a fair test, in which order do you think the ice will melt, starting with the slowest? Give an explanation for your answer. **(4)**

ii How can this investigation show that water is a poor conductor? **(3)**

(Total 10 marks)

5 This question is about PV **(photovoltaic) cells.** A student wanted find the best angle to set up a PV cell to get the maximum amount of energy transferred from the Sun's rays to electrical energy. Here is the apparatus she set up and the results she obtained.



Angle θ / degrees	0	10	20	30	40	50	60	70	80	90
Current / mA	117	144	155	189	202	208	210	204	191	172

The PV cell was connected to a load and she measured the current, *I*, produced by the cell with the cell at different angles, θ, to the horizontal.

a State:

i the dependent variable **(1)**

ii the independent variable **(1)**

iii a control variable. **(1)**

SKILLS INTERPRETATION 7th

b On a graph grid, 18 cm by 22 cm, plot a graph of the current produced by the PV cell against the angle of the cell to the horizontal. **(5)**

SKILLS PROBLEM SOLVING 5th 6th

c Use the graph to find:

i any anomalous result **(1)**

ii the angle to get the maximum output from the PV cell in the set-up shown. **(1)**

SKILLS EXECUTIVE FUNCTION

d When installing PV panels it is important to have them pointing towards the Sun as you would expect. In the experimental set-up shown, the lamp is modelling conditions in the UK in early March at midday (when the Sun reaches its highest position in the sky).

i How could the experiment be set up to model different positions of Sun? **(1)**

SKILLS INTERPRETATION 7th

ii The experiment is repeated by another student at a time and place when the Sun is directly overhead at midday. Sketch a line on your graph to show how this student's results might appear. Label this line 'Sun overhead'. **(3)**

(Total 14 marks)

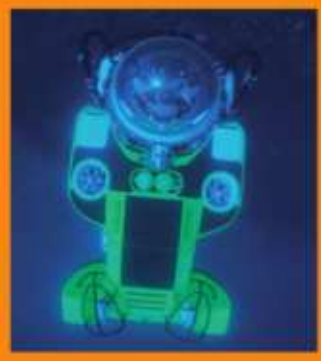
PHYSICS UNIT 5 SOLIDS, LIQUIDS AND GASES

Matter can exist in three basic forms: as a solid, a liquid or a gas. In this photo all three are present, though we can only see the solid iceberg and the liquid ocean. Fortunately the iceberg is surrounded by gas, the mixture of oxygen and nitrogen that makes up our atmosphere. Our atmosphere usually contains some water in gas form, which we cannot see. When gaseous water in the atmosphere condenses into tiny water droplets we can see these as clouds.



13 DENSITY AND PRESSURE

One way of characterising materials is by their density. This chapter looks at density and at how materials can affect things around them by exerting pressure.


▲ Figure 13.1 Some effects of density and pressure

LEARNING OBJECTIVES

- Know and use the relationship between density, mass and volume:
  $\text{density} = \frac{\text{mass}}{\text{volume}}$ $\rho = \frac{m}{V}$
- Practical: investigate density using direct measurements of mass and volume
- Know and use the relationship between pressure, force and area:
  $\text{pressure} = \frac{\text{force}}{\text{area}}$ $p = \frac{F}{A}$
- Understand how the pressure at a point in a gas or liquid at rest acts equally in all directions
- Know and use the relationship for pressure difference:
  pressure difference = height × density × gravitational field strength
  $p = h \times \rho \times g$

UNITS

In this section you need to use degree Celsius (°C) and Kelvin (K) as the units of temperature (these units both represent the same change in temperature but the Kelvin scale starts from absolute zero, as explained later), kilogram per cubic metre (kg/m^3) as the unit of density, cubic metre (m^3) as the unit of volume, pascal (Pa) as the unit of pressure and square metre (m^2) as the unit of area. It is important to remember 1 m^3 = 1 000 000 cm^3 (a cubic metre is 1 million cubic centimetres) and 1 m^2 = 10 000 cm^2 (a square metre is 10 thousand square centimetres).

KEY POINT

ρ is the Greek letter rho (pronounced 'row') and is the usual symbol for density. This is not to be confused with p which represents pressure.

The properties of a material affect how it behaves, and how it affects other materials around it. The balloon can fly because the gas inside it has a very low density. The skis spread the weight of the skier over the snow so she does not sink into it. The submersible is designed to explore the seabed – it has a very strong hull to withstand the high pressure from water deep in the oceans.

DENSITY

Solids, liquids and gases have different properties and characteristics. One such characteristic is density. Solids are often very dense – that is, they have a high mass for a certain volume. Liquids are often less dense than solids, and gases have very low densities.

The density (ρ) of a material can be calculated if you know the mass (m) of a certain volume (V) of the material, using this equation:

$$\text{density, } \rho = \frac{\text{mass, } m}{\text{volume, } V}$$

$$\rho = \frac{m}{V}$$

The units for density depend on the units used for mass and volume. If mass is measured in kilograms and volume in cubic metres, the units for density are kilograms per cubic metre (kg/m^3). Density can also be measured in grams per cubic centimetre (g/cm^3).

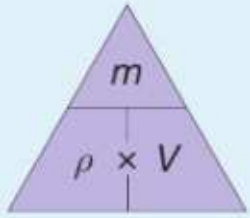
EXAMPLE 1

A piece of iron has a mass of 390 kg and a volume of 0.05 m^3. What is its density?

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{390 \text{ kg}}{0.05 \text{ m}^3}$$

$$= 7800 \text{ kg/m}^3$$



▲ Figure 13.2 The equation for density can be rearranged using the triangle method.

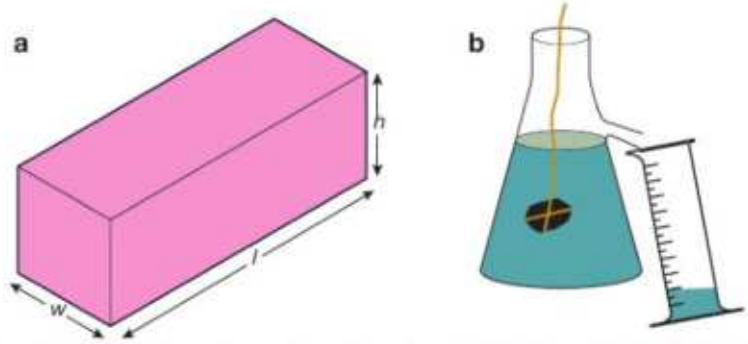
HINT

If an examination question asks you to write out the equation for calculating density, mass or volume, always give the actual equation in words or using standard symbols, such as $\rho = \frac{m}{V}$.

ACTIVITY 1

▼ PRACTICAL: INVESTIGATE THE DENSITY OF SOLIDS

The density of a substance can be determined by measuring the mass and volume of a sample of the material, and then calculating the density.



▲ Figure 13.3 **a** The volume of a regular solid can be calculated by multiplying its length (l), width (w) and height (h). **b** The volume of an irregular object can be determined using a displacement can and a measuring cylinder.

Use a half-metre rule to measure the length, width and height of a regular solid. When measuring the volume of the liquid that is displaced (pushed out) by an irregular solid make sure that the measuring cylinder is on a level (horizontal) surface and that you look at the scale straight on as shown (to avoid **parallax error**).

You then need to measure the mass of the solid. Use weighing scales for this.

EXAMPLE 2

The mass of 50 cm^3 of a liquid and a measuring cylinder is 146 g. The mass of the empty measuring cylinder is 100 g. What is the density of the liquid in kg/m^3?

mass of 50 cm^3 of liquid = 146 g – 100 g

= 46 g

= 0.046 kg

50 cm^3 = 0.000 05 m^3

$$\rho = \frac{m}{V}$$

$$= \frac{0.046 \text{ kg}}{0.000\,05 \text{ m}^3}$$

= 920 kg/m^3

or

$$= \frac{46 \text{ g}}{50 \text{ cm}^3}$$

= 0.92 g/cm^3

= 920 kg/m^3

HINT

Check the units when you are working out density – don't mix up g and m^3, for example. Also check which units the question asks for in your final answer.

1 kg = 1000 g

To convert kg to g, divide by 1000.

1 m^3 = 1 000 000 cm^3

To convert cm^3 to m^3, divide by 1 000 000 (or 10^6).

Alternatively, work out the density in g/cm^3, then multiply your answer by 1000.

PRESSURE UNDER A SOLID

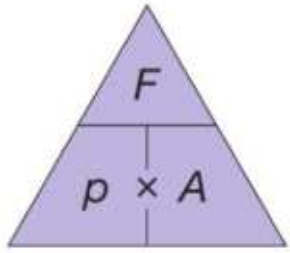
You can push a drawing pin into a piece of wood quite easily, but you cannot make a hole in the wood with your thumb, no matter how hard you push! The small point of the drawing pin concentrates all your pushing force into a tiny area, so the pin goes into the wood easily. Similarly, it is easier to cut things with a sharp knife than a blunt one, because with a sharp knife all the force is concentrated into a much smaller area.

Pressure is defined as the force per unit area. Force is measured in newtons (N) and area is measured in square metres (m^2). The units for pressure are pascals (Pa), where 1 Pa is equivalent to 1 N/m^2.

Pressure (p), force (F) and area (A) are linked by the following equation:

$$\text{pressure, } p \text{ (pascals)} = \frac{\text{force, } F \text{ (newtons)}}{\text{area, } A \text{ (square metres)}}$$

$$p = \frac{F}{A}$$



▲ Figure 13.4 The equation for pressure can be rearranged using the triangle method.

REMINDER

When answering questions, start with the equation you need to use in words or recognised symbols.

EXAMPLE 3

An elephant has a weight of 40 000 N, and her feet cover a total area of 0.1 m^2.

A woman weighs 600 N and the total area of her shoes in contact with the ground is 0.0015 m^2. Who exerts the greatest pressure on the ground?

Elephant:

$$p = \frac{F}{A}$$

$$= \frac{40\,000\ \text{N}}{0.1\ \text{m}^2}$$

$$= 400\,000\ \text{Pa (or 400 kPa)}$$

Woman:

$$p = \frac{F}{A}$$

$$= \frac{600\ \text{N}}{0.0015\ \text{m}^2}$$

$$= 400\,000\ \text{Pa (or 400 kPa)}$$

They both exert an equal pressure.



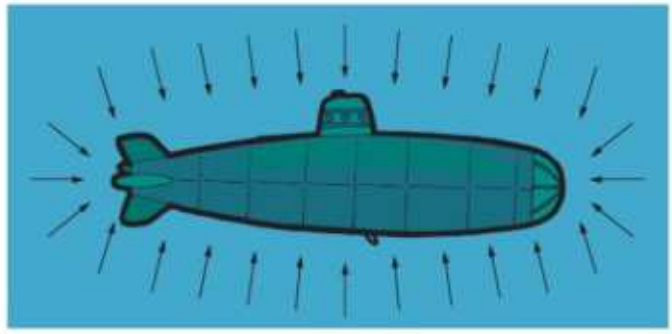
▲ Figure 13.5 **a** The caterpillar tracks on this vehicle spread its weight over a large area. **b** Camels have large feet so they are less likely to sink into loose sand.

Some machines, including cutting tools like scissors, bolt cutters and knives, need to exert a high pressure to work well. In other applications, a low pressure is important. Tractors and other vehicles designed to move over mud have large tyres that spread the vehicle's weight. The pressure under the tyres is relatively low, so the vehicle is less likely to sink into the mud. Caterpillar tracks used on bulldozers and other earth-moving equipment serve a similar purpose. (In Figure 13.5a the caterpillar tracks are very large.)

PRESSURE IN LIQUIDS AND GASES

The submersible shown in Figure 13.1 has a very strong hull to withstand the high pressure **exerted** on it by seawater. Pressure in liquids acts equally in all directions, as long as the liquid is not moving. You can easily demonstrate this using a can with holes punched around the bottom, as shown in Figure 13.6. When the can is filled with water, the water is forced out equally in all directions.

Gases also exert pressure on things around them. The pressure exerted by the atmosphere on your body is about 100 000 Pa (although the pressure varies slightly from day to day). However, the pressure inside our bodies is similar, so we do not notice the pressure of the air.





▲ Figure 13.6 Pressure in liquids acts equally in all directions. A can of water with holes can be used to demonstrate this.

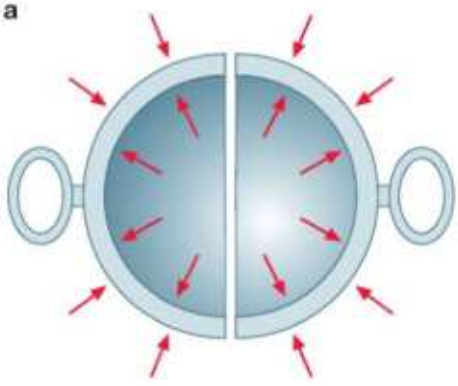
One of the first demonstrations of the effects of air pressure was carried out by Otto van Guericke in 1654, in Magdeburg, Germany. Van Guericke had two large metal bowls made, put them together and then pumped the air out. The bowls could not be pulled apart, even when he attached two teams of horses to the bowls.



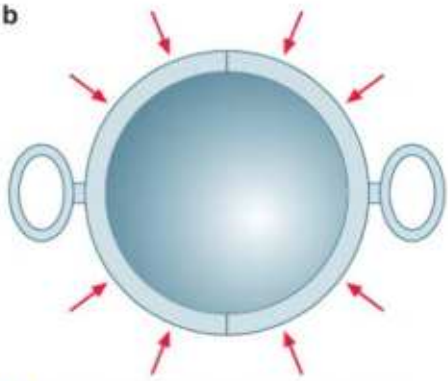
▲ Figure 13.7 Van Guericke's experiment at Magdeburg

You can do the same experiment in the laboratory, using much smaller bowls called Magdeburg **hemispheres**. When air is inside the spheres, the pressure is the same inside and outside. If the air is sucked out, pressure is only acting from the outside. The hemispheres cannot be pulled apart until air is let back into them.

a



b



▲ Figure 13.8 **a** When the hemispheres are full of air, the forces are the same inside and outside. **b** When the air is taken out, there is only a force on the outside of the hemispheres.

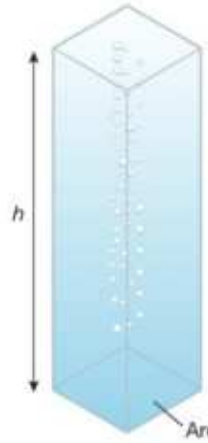
EXAMPLE 4

A laboratory set of Magdeburg hemispheres has a surface area of 0.045 m^2. What is the total force on the outside of the hemispheres?

$$F = p \times A$$
$$= 100\,000 \text{ Pa} \times 0.045 \text{ m}^2$$
$$= 4500 \text{ N}$$



▲ Figure 13.9 Pressure in a liquid increases with depth.



▲ Figure 13.10 We can work out the pressure difference between two points in a liquid by considering a column of the liquid.

KEY POINT

You need to learn this equation but you do not need to know the proof given here for the exam.

PRESSURE AND DEPTH

The experiment shown in Figure 13.9 demonstrates that the pressure in a liquid increases with depth. We can work out the pressure difference by thinking about a column of water, as shown in Figure 13.10.

The force at the bottom of the column is equal to all the weight of water above it. The volume of this water (V) is found by multiplying the area of its base (A) by the height (h) of the column. We can work out the mass (m) of the water by multiplying the volume ($A \times h$) by the density (ρ).

$$\text{mass of water, } m = (A \times h) \times \rho$$

The force (F) on the bottom of the water column is equal to the weight of this volume of water, which is the mass, m ($A \times h \times \rho$), multiplied by the gravitational field strength (g) (see page 520).

$$F = (A \times h \times \rho) \times g$$

As we are concerned with the pressure on the base of the column, we divide the force by the area:

$$F = \frac{A \times h \times \rho \times g}{A}$$

The area of the column therefore does not matter, and we can calculate the pressure difference between two points in a liquid using the equation:

pressure difference, p (Pa) = height, h (m) × density, ρ (kg/m^3) × gravitational field strength, g (N/kg)

$$p = h \times \rho \times g$$

Be careful not to muddle the symbol for pressure, p, with the symbol for density, ρ.

This equation can be used for calculating pressure differences in other liquids or gases, as long as you know their densities.

EXAMPLE 5

The first experiments on air pressure were carried out using a simple barometer. This was made by filling a long glass tube with mercury, and then inverting it into a bowl of mercury. The mercury falls until the weight of the column is supported by the pressure of the air on the mercury in the bowl.

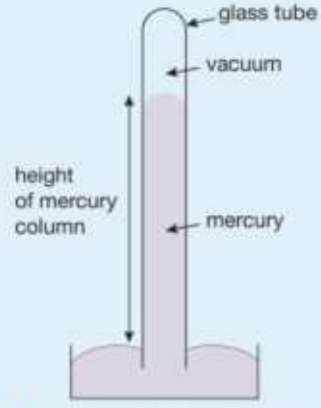
If the column of mercury is 0.74 m high, what is the air pressure?

The density of mercury is 13 600 kg/m^3. Take the gravitational field strength as 10 N/kg.

$p = h \times \rho \times g$

$= 0.74 \text{ m} \times 13\,600 \text{ kg/m}^3 \times 10 \text{ N/kg}$

$= 100\,640 \text{ Pa}$

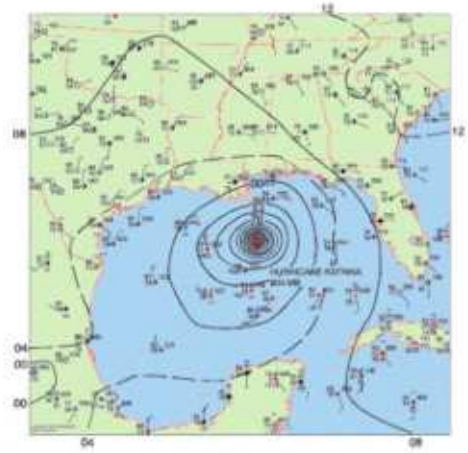


▲ Figure 13.11 A simple mercury barometer

EXTENSION WORK

The unit for pressure is named after Blaise Pascal (1623–1662). He was the first person to demonstrate that air pressure decreases with height. He persuaded his brother-in-law to take a mercury barometer up a mountain and measure the air pressure at different stages in the climb. He also arranged for someone at the base of the mountain to measure the air pressure at different times during the day. The measurements showed that the pressure of the air does decrease as you climb.

LOOKING AHEAD – WEATHER AND PRESSURE



▲ Figure 13.12 Weather maps show isobars (lines of equal air pressure). The centre of hurricane Katrina is a very low pressure region surrounded by isobars that are very close together. The result of the pressure difference is very strong winds.



▲ Figure 13.13 Tornados regularly cause huge amounts of damage in many parts of the world.

Variations in atmospheric pressure are partly responsible for the weather systems around the world. Meteorologists produce maps showing how atmospheric pressure varies from place to place to help them make predictions about future weather systems. Regions of low pressure produce winds as air flows from surrounding areas of high pressure.

Sometimes the wind speeds cause violent weather systems with tornados and hurricanes causing extensive damage and loss of life. Physics provides important tools to enable meteorologists to make more accurate predictions about when and where these devastating events will occur.

CHAPTER QUESTIONS

More questions on density and pressure can be found at the end of Unit 5 on page 635.

SKILLS CREATIVITY, REASONING

6th

1 A Greek scientist called Archimedes was asked to check the purity of the gold in a crown. He did this by comparing the density of the crown with the density of pure gold.

a Describe how he could have measured the density of an irregular-shaped object such as a crown.

SKILLS PROBLEM SOLVING

8th

b Pure gold has a density of 19 000 kg/m^3. Suppose the crown had a volume of 0.0001 m^3. What mass should the crown be if it is made of pure gold?

2 People working on the roofs of buildings often lay a ladder or plank of wood on the roof. They walk on the ladder rather than the roof itself.

SKILLS REASONING

6th

a Explain why using a ladder or plank will help to prevent damage to the roof.

SKILLS PROBLEM SOLVING

7th

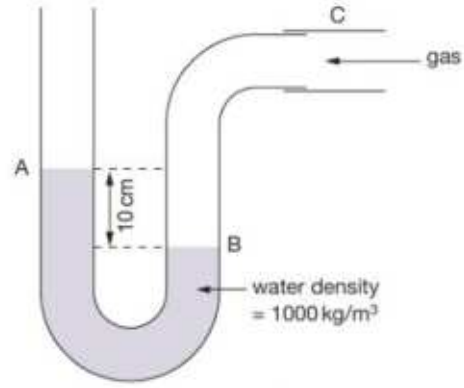
b A workman's weight is 850 N, and each of his boots has an area of 210 cm^2. Calculate the maximum pressure under his feet when he is walking. Give your answer in pascals.

c The workman lays a plank on the roof. The plank has an area of 0.3 m^2 and a weight of 70 N. What is the maximum pressure under the plank when he is walking on it?

HINT

Remember that all your weight is on one foot at some point while you are walking. To convert cm^2 to m^2, divide by 10 000 or 10^4.

3 A manometer can be used to find the pressure of a gas. The difference in the level of the liquid in each side of the tube indicates the difference in pressure on the water surface at A and the pressure of the gas on the water surface at B. (Assume atmospheric pressure is 100 kPa.)



a What is the difference in pressure in Pa between A and B? Use g = 10 N/kg.

b What is the pressure of the gas in tube C?

SKILLS REASONING

c Describe what will happen when the gas is turned off and the pipe is removed from C.

14 SOLIDS, LIQUIDS AND GASES

All matter is made up of particles that are continuously moving. The arrangement and movement of the particles determine the properties of the material. In gases, scientists have discovered laws that describe the relationship between pressure, temperature and volume. In this chapter, you will learn what these laws are and how this relationship can be explained in terms of the behaviour of the particles.



▶ Figure 14.1 The botanist Robert Brown (1773–1858) made an observation while studying pollen grains under a microscope that has become known as Brownian motion in his honour. The observation led to the kinetic theory of matter that we use to explain the behaviour of solids, liquids and gases.

LEARNING OBJECTIVES

- Explain how molecules in a gas have random motion and that they exert a force and hence a pressure on the walls of a container
- Understand why there is an absolute zero of temperature which is –273 °C
- Describe the Kelvin scale of temperature and be able to convert between the Kelvin and Celsius scales
- Understand why an increase in temperature results in an increase in the average speed of gas molecules
- Know that the Kelvin temperature of a gas is proportional to the average kinetic energy of its molecules
- Explain, for a fixed amount of gas, the qualitative relationship between:
  - pressure and volume at constant temperature
  - pressure and Kelvin temperature at constant volume
- Use the relationship between the pressure and Kelvin temperature of a fixed mass of gas at constant volume:
  $$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$
- Use the relationship between the pressure and volume of a fixed mass of gas at constant temperature:
  $$p_1V_1 = p_2V_2$$

THE GAS LAWS

We are now going to focus our attention on the properties of gases. We shall explain the different properties in terms of the movement of particles.

We have already said that gases are made up of molecules that are moving. We believe that the particles in gases are spread out and constantly moving in a random, haphazard way.

When the molecules hit the walls of a container they exert a force. The combined effect of the huge number of **collisions** results in the pressure that is exerted on the walls of the container.

SOLIDS, LIQUIDS AND GASES

BOYLE'S LAW



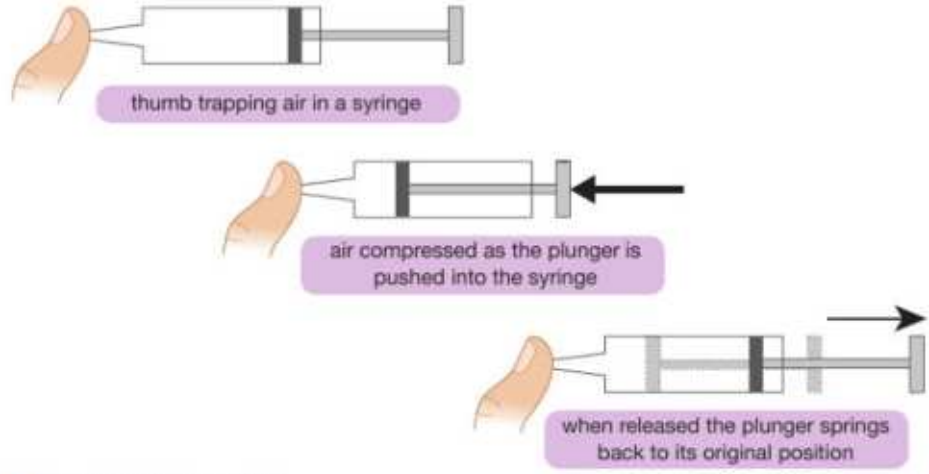
▲ Figure 14.2 Robert Boyle (1627–1691) was an Anglo-Irish chemist and philosopher. As well as discovering the law that bears his name, he worked with Robert Hooke at Oxford developing the air pump.



▲ Figure 14.4 A modern version of Boyle's experiment to see how the volume of a gas depends on the pressure exerted on it.

Safety note: Eye protection is needed in case any tubing leaks or detaches, which will cause gas under high pressure to be ejected.

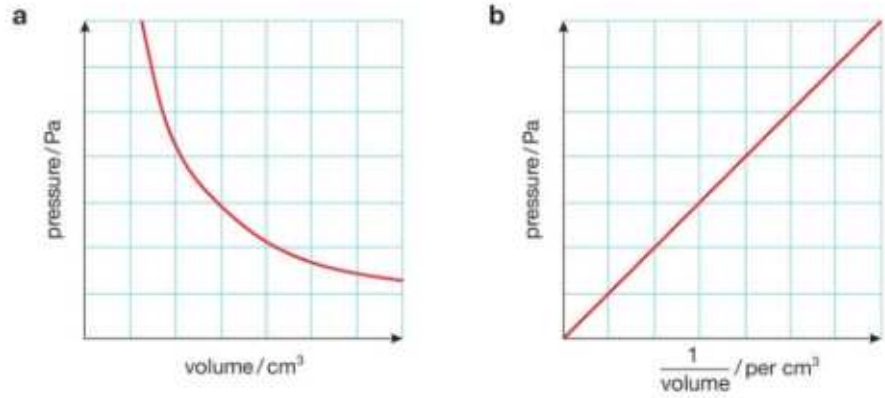
The scientist Robert Boyle (Figure 14.2) discovered something that you have probably noticed if you have ever used a bicycle pump: air is squashy! He noticed that you can squeeze air in a cylinder and that it springs back to its original volume when you release it. You can try this for yourself with a plastic syringe (Figure 14.3).



▲ Figure 14.3 Air is squashy!

Boyle devised an experiment to see how the volume occupied by a gas depends on the pressure exerted on it. Pressure is the force acting per unit area. This is measured in N/m^2. One N/m^2 is called a pascal (Pa). A version of Boyle's experiment is shown in Figure 14.4.

Boyle took care to make sure that the trapped gas he was studying stayed at the same temperature. He increased the pressure on the gas and made a note of the new volume. His results looked like the graph shown in Figure 14.5a.



▲ Figure 14.5 **a** Graph to show how the pressure of a gas at constant temperature varies with the volume; **b** Graph of pressure against $\frac{1}{\text{volume}}$

Boyle noticed that when he doubled the pressure, the volume of the gas halved. If we plot pressure (p), against $\frac{1}{\text{volume}}$ $\left(\frac{1}{V}\right)$, as in Figure 14.5b, we can see from the straight line passing through the origin that p is proportional to $\frac{1}{V}$. This discovery, called Boyle's law, is expressed in the equation:

$$p_1 V_1 = p_2 V_2$$

This means that if you take a fixed mass of gas that has a pressure p_1 and a volume V_1 and change either the pressure or the volume, the new pressure p_2 multiplied by the new volume V_2 will be the same as $p_1 \times V_1$, if the temperature of the gas remains the same.

EXAMPLE 1

Atmospheric pressure is 100 kPa (100 000 Pa). Some air in a sealed container has a volume of 2 m^3 at atmospheric pressure. What would be the pressure of the air if you reduced its volume to 0.2 m^3?

First write down what we know:

$$p_1 = 100 \text{ kPa}$$
$$V_1 = 2 \text{ m}^3$$
$$V_2 = 0.2 \text{ m}^3$$
$$p_1V_1 = p_2V_2$$
$$p_2 \times 0.2 \text{ m}^3 = 100 \text{ kPa} \times 2 \text{ m}^3$$
$$p_2 = \frac{100 \text{ kPa} \times 2 \text{ m}^3}{0.2 \text{ m}^3}$$
$$= 1000 \text{ kPa}$$

HINT

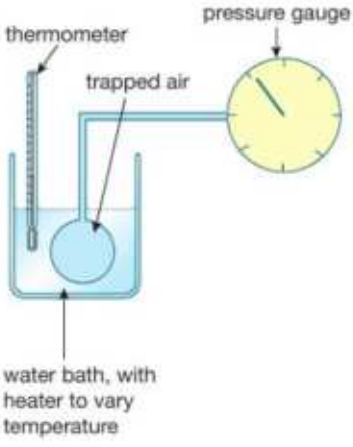
You can do all your working in kPa if you wish, rather than converting the pressure to pascals. You can also use cubic centimetres for volume if these units are given in the question. It does not matter which units you use, as long as you use the same ones throughout the question.

Gases can be compressed because the gas molecules are very spread out. When a gas is squashed into a smaller container it presses on the walls of the container with a greater pressure. This is explained in terms of particle theory as follows.

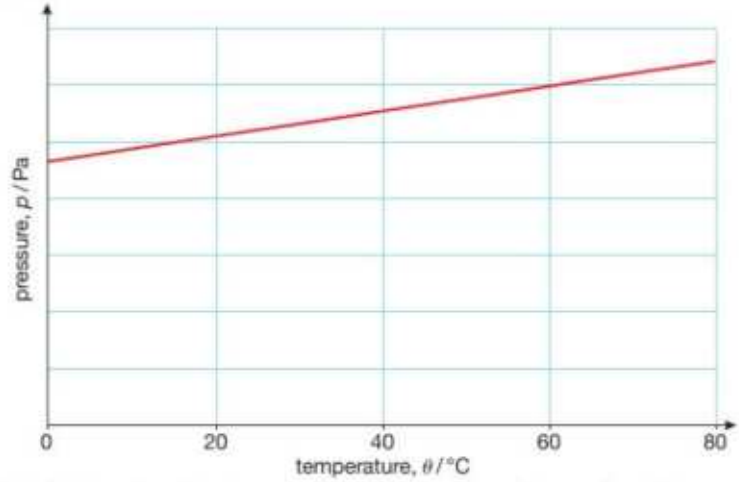
If the gas is kept at the same temperature, the average speed of the particles stays the same. (Remember that temperature is an indication of the kinetic energy of the particles.) If the same number of particles is squeezed into a smaller volume, they will hit the container walls more often. Each particle exerts a tiny force on the wall with which it collides. More collisions per second means a greater average force on the wall and, therefore, a greater pressure.

ABSOLUTE ZERO

Boyle took care to conduct his experiment at constant temperature. He was aware that temperature also had an effect on the pressure of a gas. Figure 14.6 shows an experiment to investigate how the pressure of a gas depends on its temperature.



▲ Figure 14.6 Simple apparatus to measure the pressure of a fixed volume of gas at a range of temperatures

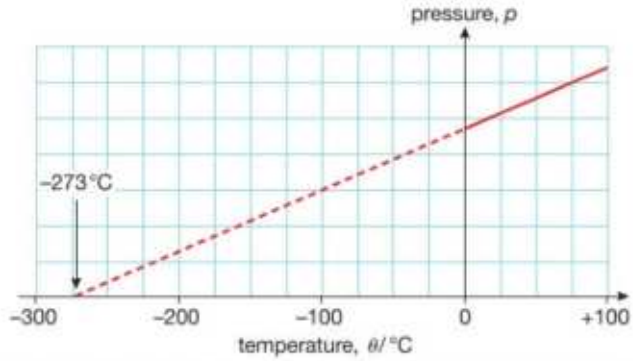


▲ Figure 14.7 Graph to show how the pressure of a fixed volume of gas varies with temperature

The gas is kept at constant volume, and its pressure is measured at a range of temperatures. The graph in Figure 14.7 shows typical results for this experiment.

The graph shows that the pressure of the gas increases as the temperature increases. We could also say that the gas pressure gets smaller as the gas is cooled.

What happens if we keep cooling the gas? The graph in Figure 14.8 shows this.



▲ Figure 14.8 At a temperature of –273 °C, the pressure of the gas would be zero. This temperature is known as 'absolute zero'.

As we cool the gas, the pressure keeps decreasing. The pressure of the gas cannot become less than zero. This suggests that there is a temperature below which it is not possible to cool the gas further. This temperature is called absolute zero. Experiments show that absolute zero is approximately –273 °C.

The Kelvin temperature scale starts from absolute zero. The Kelvin temperature of a gas is proportional to the average kinetic energy of its molecules.

To convert a temperature on the Celsius scale (in °C) to a Kelvin scale temperature (in K), add 273 to the Celsius scale temperature:

- temperature in K = temperature in °C + 273
- temperature in °C = temperature in K – 273

EXAMPLE 2

a At what temperature does water freeze, in Kelvin?

Water freezes at 0 °C. To convert 0 °C to Kelvin:

$T = (0\,°C + 273)\,K$

$= 273\,K$

b What is room temperature, in Kelvin?

Typical room temperature is 20 °C, so:

$T = (20\,°C + 273)\,K$

$= 293\,K$

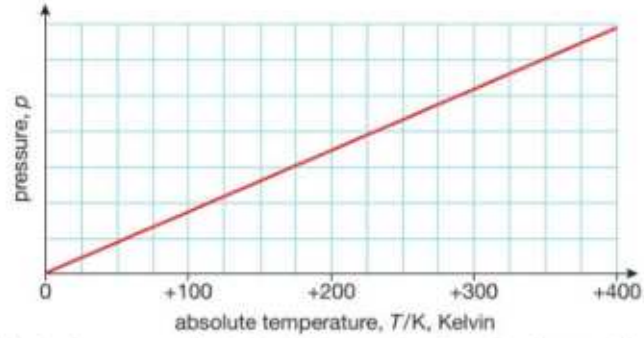
c What temperature is 400 K on the Celsius scale?

$\theta = (400\,K - 273)\,°C$

$= 127\,°C$

If we redraw the graph of pressure against temperature using the absolute or Kelvin temperature scale, we get a graph that is a straight line passing through

the origin, as shown in Figure 14.9. This shows that the pressure of the gas is proportional to its Kelvin temperature. For example, if you heat a gas from 200 K (–73 °C) to 400 K (127 °C), its pressure will double.



▲ Figure 14.9 Graph of pressure against absolute temperature for a fixed amount of gas at constant volume

For a fixed mass of gas at a constant volume:

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

NB T must be measured in Kelvin.

KEY POINT

We often use the symbol θ for temperature in °C. For temperature in K we always use the symbol T. Remember to convert Celsius temperatures to Kelvin when using gas law equations in which temperature change occurs.

EXAMPLE 3

You take an empty tin and put the lid on tightly. You heat it using a Bunsen burner until the temperature of the air inside is 50 °C. What is the pressure of the air inside the tin? The temperature of the room is 20 °C.

First write down what you know:

p_1 = 100 kPa (this is atmospheric pressure)

The starting temperature is 20 °C, but we must change this to Kelvin, so:

$T_1 = 20 + 273$ K = 293 K.

The end temperature, 50 °C, must also be converted so:

$T_2 = 50 + 273$ K = 323 K

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$p_2 = p_1 \times \frac{T_2}{T_1}$$

$$= 100 \text{ kPa} \times \frac{323 \text{ K}}{293 \text{ K}}$$

$$= 110 \text{ kPa}$$

EXTENSION WORK

Cooling things further becomes more and more difficult as they get closer to 0 K. Scientists have managed to cool gases down to within a few thousandths of a degree above absolute zero. At this temperature, even gases like helium and hydrogen can be liquefied. The gas laws do not apply once a gas is either cooled or compressed (forced into a small volume) to the point that they become liquid.

The relationship can be explained as follows.

The number of gas particles and the space, or volume, they occupy remain constant. When we heat the gas the particles continue to move randomly, but with a higher average speed. This means that their collisions with the walls of the container are harder and happen more often. This results in the average pressure exerted by the particles increasing.

When we cool a gas the kinetic energy of its particles decreases. The lower the temperature of a gas the less kinetic energy its particles have – they move more slowly. At absolute zero the particles have no thermal or movement energy, so they cannot exert a pressure.

CHAPTER QUESTIONS

More questions on solids, liquids and gases can be found at the end of Unit 5 on page 635.

SKILLS CRITICAL THINKING

1 Explain how ideas about particles can account for the absolute zero of temperature.

SKILLS PROBLEM SOLVING

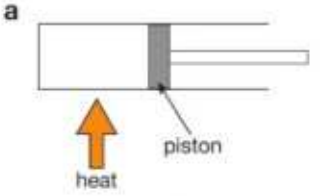
2 a Convert the following Celsius temperatures to Kelvin temperatures.
- i 0 °C
- ii 100 °C
- iii 20 °C

b Convert the following Kelvin temperatures to Celsius temperatures.
- i 250 K
- ii 269 K
- iii 305 K

SKILLS ANALYSIS

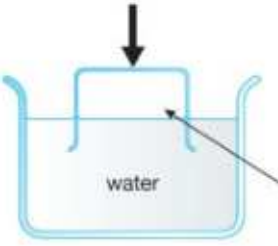
3 State what happens in the situations shown in the diagram. Explain your answers using ideas about particles.

a



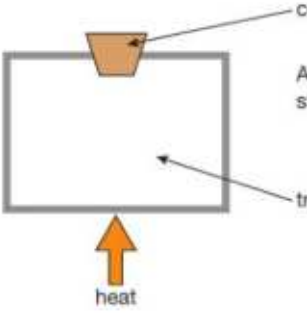
Some air, trapped in a cylinder by a low friction piston, is heated.

b



A small beaker with some air trapped inside it is pushed down into a larger beaker of water.

c



A rigid container with a cork stopping its opening is heated.

UNIT QUESTIONS

SKILLS PROBLEM SOLVING 7m 1

a A rectangular block of metal of density 8000 kg/m^3 measures 2 cm by 3 cm by 10 cm. What is the mass of the block?

A 48 g

B 0.48 kg

C 4.8 kg

D 48 kg **(1)**

b Which of the following will exert the greatest pressure when standing on the ground?

A an elephant: weight 50 000 N, area of one foot 0.2 m^2

B atmospheric pressure: 10^5 Pa

C ballerina: weight 450 N, on one point, area 0.0015 m^2

D man: weight 800 N, area of one foot 0.025 m^2 **(1)**

SKILLS CRITICAL THINKING 5m

c Which of the following descriptions most accurately describes a gas?

A very low density, easily compressed, cannot flow

B high density, cannot be compressed, definite shape

C very low density, easily compressed, expands to fill available space

D high density, difficult to compress, can flow **(1)**

d The specific heat capacity of a liquid is

A the amount of heat energy required to make 1 kilogram of the liquid boil

B the amount of heat energy required to raise the temperature of 1 kilogram of the liquid by 1 °F

C the amount of heat energy required to raise the temperature of 1 kilogram of the liquid by 1 °C

D the amount of heat energy required to raise the temperature of 1000 cm^3 of the liquid by 1 °C **(1)**

e Boyle's law states that

A if you double the pressure on a gas its volume doubles

B if you double the pressure on a gas its temperature halves

C if you double the pressure on a gas its volume doubles provided its temperature is constant

D if you double the pressure on a gas its volume halves provided its temperature is constant **(1)**

(Total 5 marks)

SKILLS INTERPRETATION

2 Look at the diagram below showing a small gas bubble in a glass of fizzy drink, like cola.



a Copy the diagram and use eight arrows to shows how the pressure of the liquid acts on the gas bubble. **(2)**

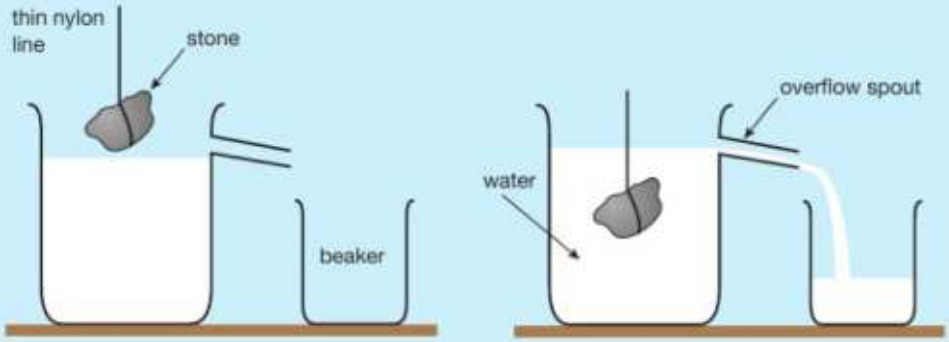
SKILLS REASONING

b Describe what happens to the bubble as it floats up towards the top of the drink and explain the reason for your answer (assume that the amount of gas in the bubble does not change as the bubble rises up through the cola). **(3)**

(Total 5 marks)

SKILLS EXECUTIVE FUNCTION

3 The diagram shows part of the apparatus used by a student to find the density of a stone.



a **i** What is the student measuring? **(1)**

ii What other piece of apparatus is required to complete the measurement? **(1)**

iii What precautions should the student take to ensure that the measurement is accurate? **(1)**

SKILLS CRITICAL THINKING

b **i** State the equation that the student needs to calculate the density of the stone. **(1)**

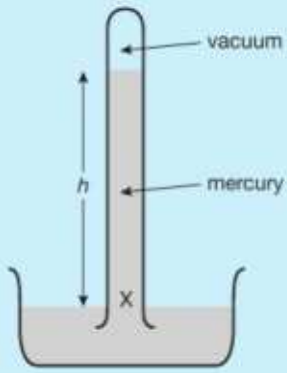
SKILLS EXECUTIVE FUNCTION

ii What other measurement must be made? State the name of the apparatus needed to make this measurement. **(1)**

(Total 5 marks)

SKILLS PROBLEM SOLVING 7th 4

The diagram shows a simple mercury barometer made by filling a strong glass tube with mercury and turning it upside down (with the open end of the tube closed) in a dish of mercury and then opening the end below the level of mercury in the dish. Mercury runs out of the tube until the pressure of the mercury at X is equal to the pressure of the air acting on the surface of the mercury in the dish.



The height, h, of mercury in the tube is a measure of air (atmospheric) pressure. A typical value for h is 76 cm.

The density of mercury is 13 600 kg/m^3. Use this value to calculate the atmospheric pressure in Pa (pascals). **(3)**

(Total 3 marks)

MAGNETISM AND ELECTROMAGNETISM 639 | ELECTRIC MOTORS AND ELECTROMAGNETIC INDUCTION 646

PHYSICS UNIT 6 MAGNETISM AND ELECTROMAGNETISM

In Norse (Norwegian) mythology the spectacular light display we call the aurora borealis was seen as a bridge of fire that connected the Earth to the sky. Nowadays we know it is caused by charged particles, emitted by the Sun, interacting with the Earth's magnetic field and atmosphere. In this section we will be looking at magnetism and the crucial role it plays in our everyday lives.



15 MAGNETISM AND ELECTROMAGNETISM

There are two types of magnets that we use in our everyday lives. These are permanent magnets and electromagnets. A permanent magnet has a magnetic field around it all the time. The strength and direction of this field is not easy to change. An electromagnet when turned on also has a magnetic field around it but its strength and direction can be changed very easily. In this chapter you will learn about the factors affecting the magnetic field around an electromagnet and how electromagnets are used in several important devices.



▲ Figure 15.1 Electromagnets can be used to lift iron or steel objects.

The huge electromagnet in Figure 15.1 is being used in a scrapyard to pick up large objects that contain iron or steel. When the objects have been moved to their new position the electromagnet is turned off and the objects fall.

LEARNING OBJECTIVES

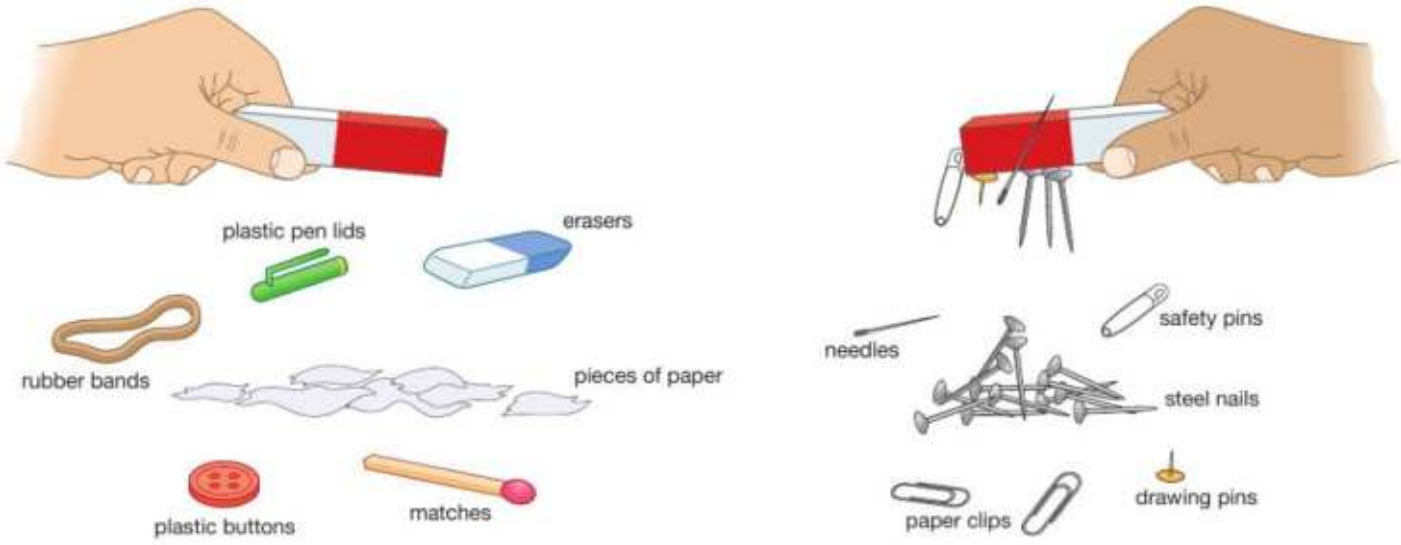
- Know that magnets repel and attract other magnets and attract magnetic substances
- Describe the properties of magnetically hard and soft materials
- Practical: investigate the magnetic field pattern for a permanent bar magnet and between two bar magnets
- Understand the term magnetic field line
- Know that magnetism is induced in some materials when they are placed in a magnetic field
- Describe how to use two permanent magnets to produce a uniform magnetic field pattern
- Know that an electric current in a conductor produces a magnetic field around it

UNITS

In this section you will need to use ampere (A) as the unit of current, volt (V) as the unit of voltage and watt (W) as the unit of power.

MAGNETISM AND MAGNETIC MATERIALS

Magnets are able to **attract** objects made from magnetic materials such as iron, steel, nickel and cobalt. Magnets cannot attract objects made from materials such as plastic, wood, paper or rubber. These are non-magnetic materials.

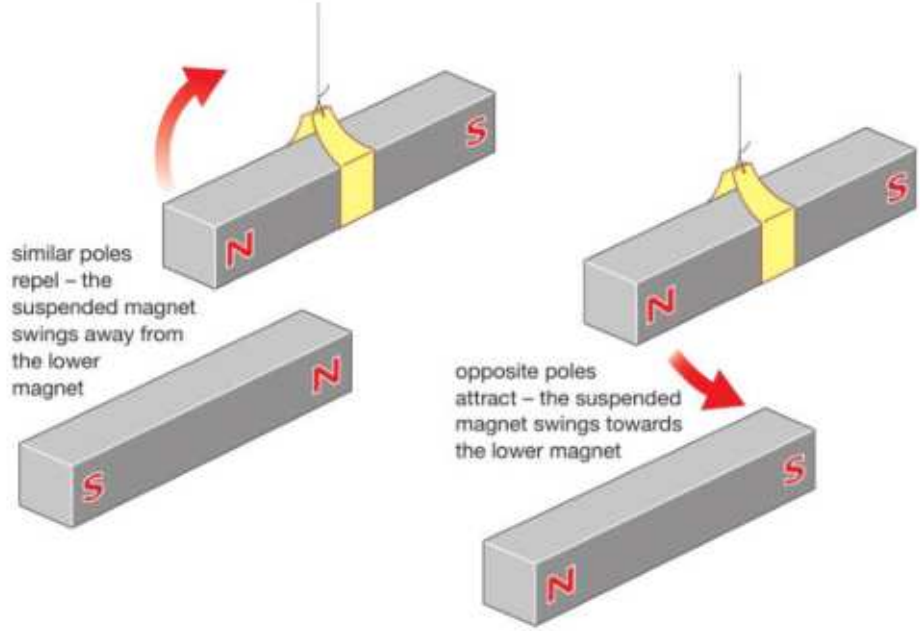


▲ Figure 15.2 Magnets attract some objects and not others.

MAGNETS

The strongest parts of a magnet are called its poles. Most magnets have two poles. These are called the north pole and the south pole.

If two similar poles are placed near to each other they **repel**. If two dissimilar (opposite) poles are placed near to each other they attract.



▲ Figure 15.3 Similar poles repel and opposite poles attract.

Permanent magnets like the bar magnets shown in Figure 15.3 are made from a magnetically hard material such as steel. A magnetically hard material keeps its magnetism once it has been magnetised. Iron is a magnetically soft material and is not suitable for a permanent magnet. Magnetically soft materials lose their magnetism easily and are therefore useful as temporary magnets.

EXTENSION WORK

Ancient travellers would construct a basic compass by placing a splinter (thin piece) of magnetised rock called lodestone onto a piece of wood floating in water. The splinter would turn to point in the direction of north–south. The end pointing towards the north was called the north pole.

MAGNETIC FIELDS

Around every magnet there is a volume of space where we can detect magnetism. This volume of space is called a **magnetic field**. Normally a magnetic field cannot be seen but we can use iron filings or plotting compasses to show its shape and discover something about its strength and direction.

ACTIVITY 1

▼ PRACTICAL: INVESTIGATE THE MAGNETIC FIELD PATTERNS OF BAR MAGNETS

1 Place a bar magnet between two books and place a sheet of paper or thin card over it.

2 Sprinkle some iron filings on the paper above the magnet.

3 Tap the paper very gently.

4 The iron filings will move to show the magnetic field pattern.

OR

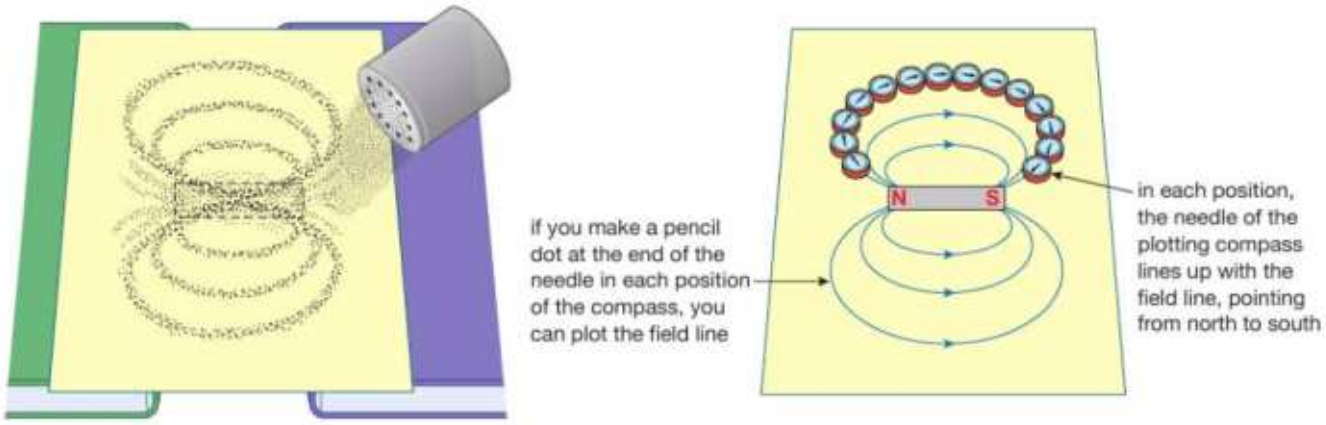
1 Place a bar magnet on a piece of paper.

2 Place a large number of small compasses on the paper near the magnet.

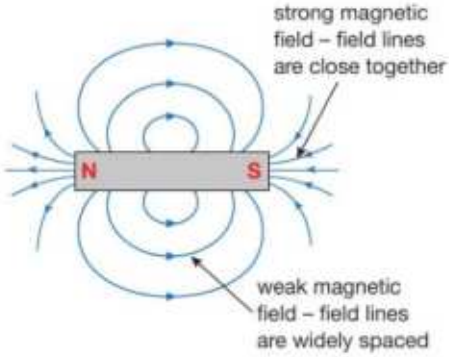
3 Look carefully at the pattern shown by the needles of the compasses.

Repeat the same experiment using two bar magnets, placing them about 5 cm apart.

Safety note: Avoid skin contact with iron filings, since they irritate the skin. Do not blow them off the paper, because they may get into the eyes, which is very painful.



▲ Figure 15.4 We can see the shape of the magnetic field around a magnet by using iron filings or plotting compasses.



▲ Figure 15.5 The magnetic field around a bar magnet follows a pattern like this.

We draw magnetic fields like that in Figure 15.5 using magnetic field lines. Magnetic field lines don't really exist but they help us to visualise the main features of a magnetic field.

The magnetic field lines:

- show the shape of the magnetic field
- show the direction of the magnetic force – the field lines 'travel' from north to south
- show the strength of the magnetic field – the field lines are closest together where the magnetic field is strongest.

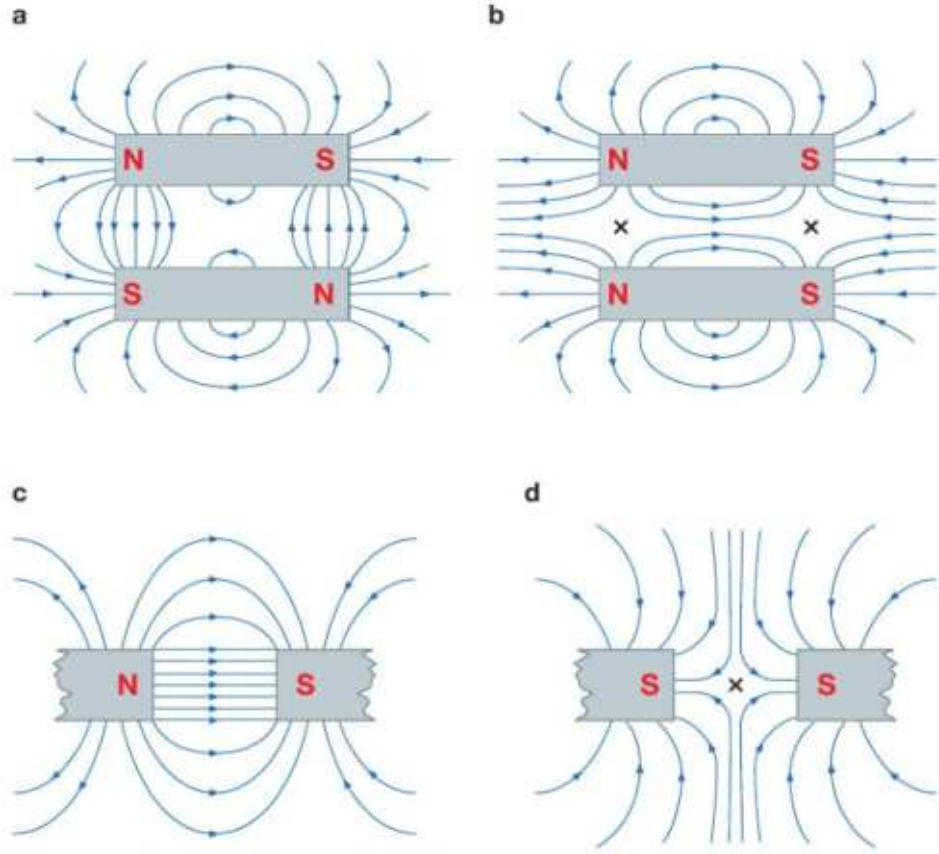
MAGNETISM AND ELECTROMAGNETISM

OVERLAPPING MAGNETIC FIELDS

If two magnets are placed near each other, their magnetic fields overlap and affect each other. We can investigate this using iron filings or plotting compasses. Figure 15.6 shows the different field patterns we would see.

EXTENSION WORK

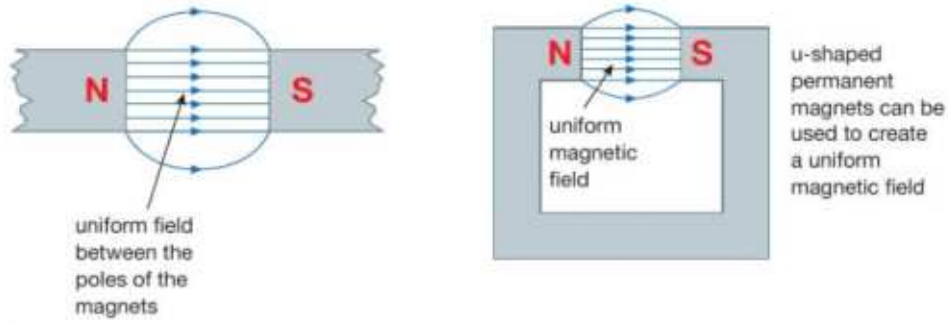
Point X in Figure 15.6 is called a neutral point. It is a position where the effects of the two magnetic fields have cancelled each other out, meaning that there is no resultant magnetic field here. Can you find any other neutral points in these magnetic field patterns?



▲ Figure 15.6 Magnetic fields around pairs of magnets

CREATING A UNIFORM MAGNETIC FIELD

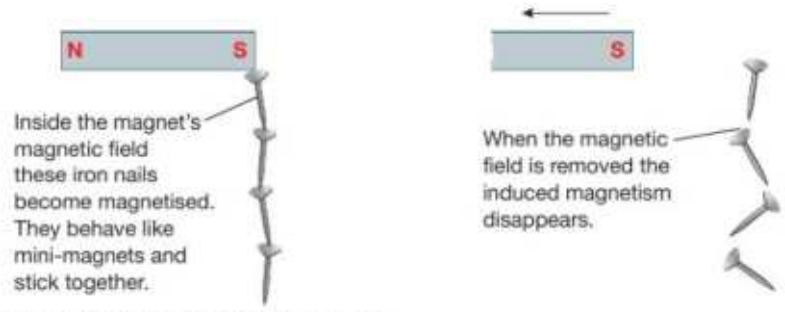
If we look very carefully at the magnetic field created between the north pole of one magnet and the south pole of a different magnet we will see that the field is shown as a series of straight field lines that are evenly spaced. A field like this is described as a uniform magnetic field – that is, its strength and direction is the same everywhere. Creating a uniform field like this is extremely useful as we will see later in this chapter and in the next chapter.



▲ Figure 15.7 Two examples of uniform magnetic fields

INDUCED MAGNETISM

If we place an object made from a magnetic material, for example, an iron nail, inside a magnetic field it becomes a magnet. We say that magnetism has been **induced** in the nail. Because iron is a magnetically soft material, its induced magnetism is temporary and disappears if the permanent magnet is removed. If the nail is made from a magnetically hard material such as steel it will retain some of its magnetism after the magnet is removed.



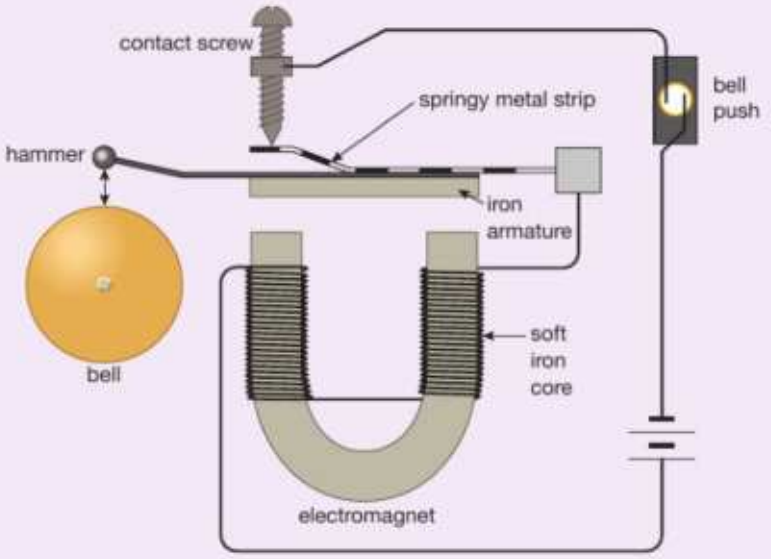
▲ Figure 15.8 Introducing magnetism in iron nails

EXTENSION WORK

It is not necessary to memorise how an electric bell or a circuit breaker works but understanding how they work might help reinforce some of the basic principles of magnets and electromagnets you will need in your exams.

The electric bell

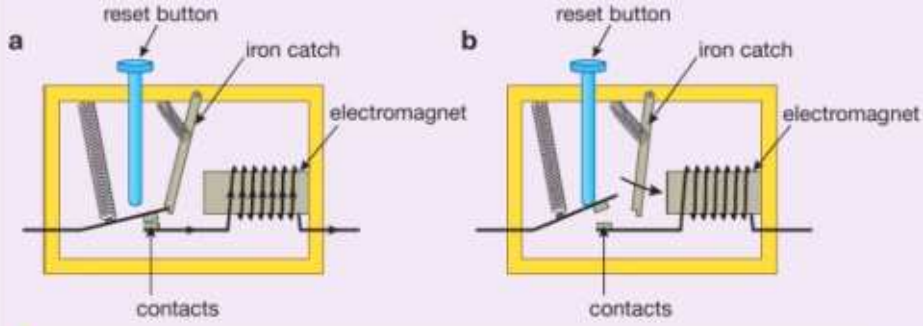
When the bell push is pressed the circuit is complete and there is current in the circuit. As a result the soft iron core of the electromagnet becomes magnetised and attracts the piece of iron that is attached to the hammer (this is called the armature). When the armature is pulled down, the hammer strikes the bell. At the same time a gap is created at the contact screw. The circuit is now incomplete and the current stops. The electromagnet is now turned off so the springy metal strip pulls the armature up to its original position.
The circuit is again complete and the whole process begins again.



▲ Figure 15.9 An electric bell relies upon an electromagnet.

Circuit breaker

Circuit breakers also use electromagnets. The circuit breaker in Figure 15.10 uses electromagnetism to cut off the current if it becomes larger than a certain value. If the current is too high the electromagnet becomes strong enough to pull the iron catch out of position so that the contacts open and the circuit breaks. Once the problem in the circuit has been corrected the catch is repositioned by pressing the reset button.



▲ Figure 15.10 a The circuit breaker allows a normal sized current. b When there is too large a current the circuit becomes incomplete.



▲ Figure 15.11 These circuit breakers control the supply of electricity to different circuits in a building. The circuit breaker will 'trip' if there is something wrong with the circuit and the current is too high.

CHAPTER QUESTIONS

More questions on electromagnetism can be found at the end of Unit 6 on page 654.

SKILLS CRITICAL THINKING

1 Which of these objects are made from magnetic materials?

a copper pipe
b plastic paper clip
c steel nail
d glass bottle
e iron bar
f rubber tyre
g nickel coins

SKILLS INTERPRETATION, REASONING

2 Draw a diagram of two bar magnets placed so that two of their poles are a repelling, and b attracting. Explain why you have drawn the magnets in these positions.

SKILLS CRITICAL THINKING

3 a What three features of a magnetic field do field lines show?

b What is a uniform magnetic field?

SKILLS INTERPRETATION

c Draw a diagram of a uniform field between two bar magnets.

SKILLS INTERPRETATION

SKILLS REASONING

4 a Draw a diagram to show the shape of the magnetic field around a **solenoid**.

b How does your diagram show where the magnetic field is strong or weak?

c Explain what happens to the magnetic field if the direction of the current through the solenoid is reversed.

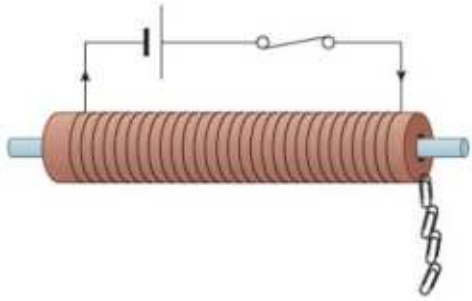
5 In 1819 a scientist named Hans Christian Oersted was using a cell to produce a current in a wire. Close to the wire there was a compass. When there was a current in the wire, Oersted noticed – much to his surprise – that the compass needle moved.

a Why did the compass needle move?

b When there is a current in a horizontal wire, the needle of a compass placed beneath the wire comes to rest at right angles to the wire, pointing from left to right. In which direction will the compass needle point if it is held above the wire? Explain your answer.

c Would your answer to part b still be correct if the direction of the current in the wire was changed? Explain your answer.

6 The diagram below shows a simple electromagnet.



a Explain why the core (centre) of an electromagnet is made of soft iron and not steel.

b Suggest two ways in which the strength of this electromagnet could be increased.

16 ELECTRIC MOTORS AND ELECTROMAGNETIC INDUCTION

Trains in many cities use electric motors to transport millions of people to and from work each day. In the first part of this chapter, we are going to look at how an electric motor works. An electric motor creates motion from an electric current. Generators and alternators, on the other hand, transfer movement or kinetic energy into electrical energy by a process called electromagnetic induction. The second part of this chapter is going to look at this process.



▲ Figure 16.1 Electric train in Bangkok (the Skytrain)

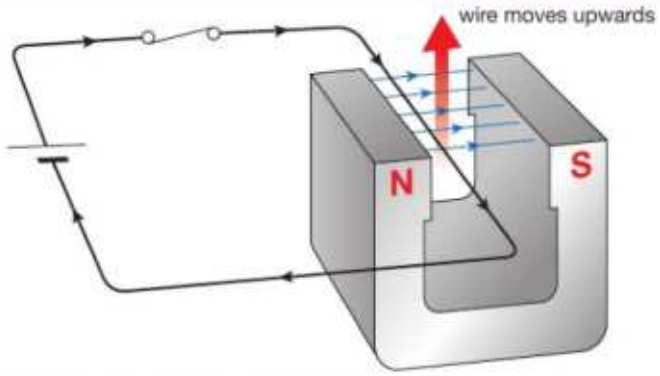
LEARNING OBJECTIVES

- Understand why a force is exerted on a current-carrying wire in a magnetic field, and how this effect is applied in simple d.c. electric motors and loudspeakers
- Use the left-hand rule to predict the direction of the resulting force when a wire carries a current perpendicular to a magnetic field
- Describe how the force on a current-carrying conductor in a magnetic field changes with the magnitude and direction of the field and current
- Know that a voltage is induced in a conductor or a coil when it moves through a magnetic field or when a magnetic field changes through it and describe the factors that affect the size of the induced voltage
- Describe the generation of electricity by the rotation of a magnet within a coil of wire and of a coil of wire within a magnetic field, and describe the factors that affect the size of the induced voltage

MOVEMENT FROM ELECTRICITY

When a charged particle moves through a magnetic field it experiences a force, as long as its motion is not parallel to the field. We can demonstrate this effect by passing electrons (that is, an electric current) along a wire that is placed in a magnetic field as shown in Figure 16.2. When the switch is closed and electrons flow, the wire will try to move upwards.

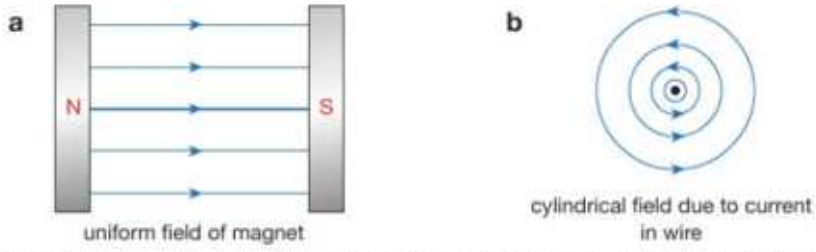
OVERLAPPING MAGNETIC FIELDS



▲ Figure 16.2 The wire moves where there is a current in it.

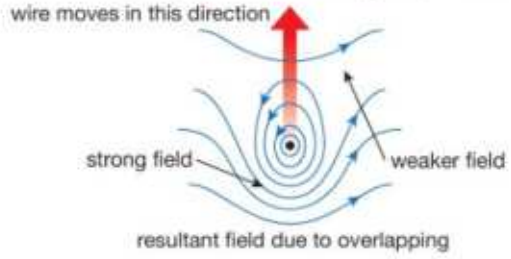
We can explain this motion by looking at what happens when the switch is closed and the two magnetic fields overlap.

The two diagrams in Figure 16.3 show the shapes and directions of the magnetic fields **a** across the poles of the magnet, and **b** around the current-carrying wire before they overlap.



▲ Figure 16.3 a Magnet's uniform magnetic field b Magnetic field around a current carrying wire

If the wire is placed between the poles of the magnet, the two fields overlap.



▲ Figure 16.4 The new magnetic field created by overlapping

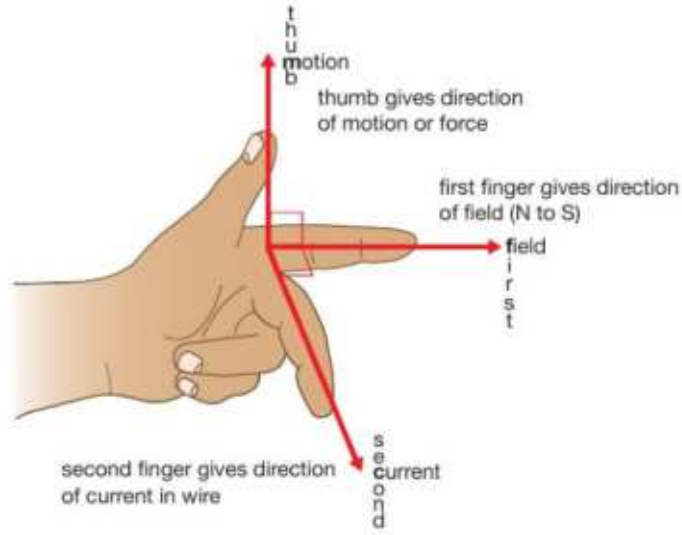
In certain places, for example, below the wire, the fields are in the same direction and so reinforce each other. A strong magnetic field is produced here. In other places, for example, above the wire, the fields are in opposite directions. A weaker field is produced here. Because the fields are of different strengths the wire 'feels' a force, pushing it from the stronger part of the field to the weaker part – that is, in this case, upwards. The overlapping of the two magnetic fields has produced motion. This is called the motor effect.

A stronger force will be produced if the magnetic field is stronger or if the current is increased.

KEY POINT

We can predict the direction of the force or movement of the wire using Fleming's left-hand rule.

If we change the direction of the current or the magnet's field, a different overlapping pattern is created and we will see the wire move in the opposite direction.

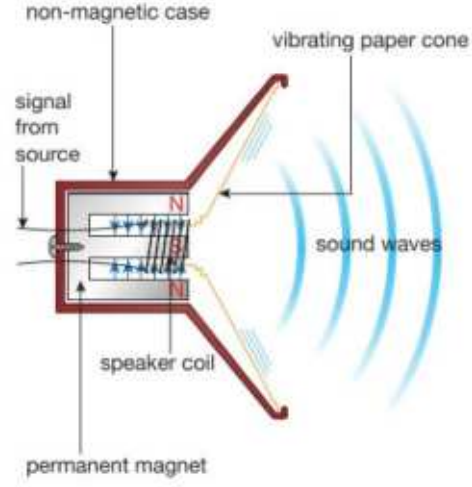


▲ Figure 16.5 Fleming's left-hand rule helps you to work out the direction of the force.

THE MOVING-COIL LOUDSPEAKER

The moving-coil loudspeaker uses the motor effect to transfer energy to create sound.

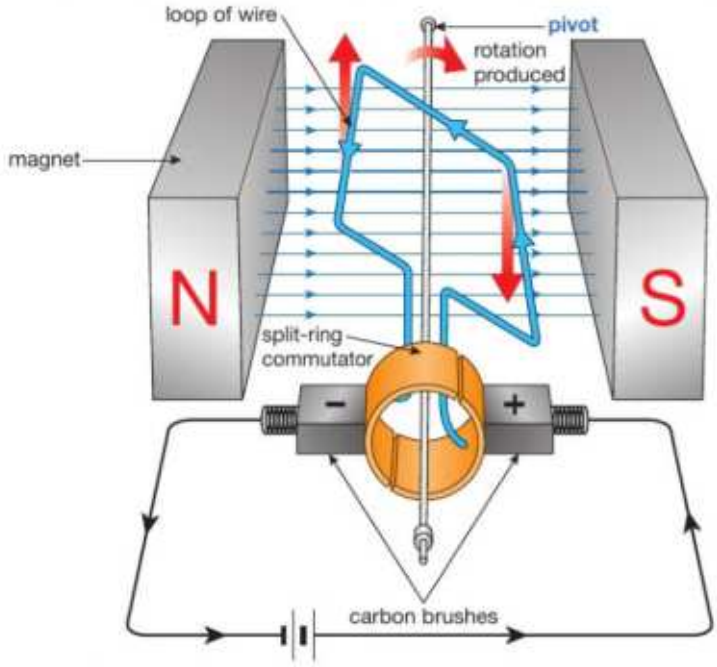
- Electric currents from a source, such as a radio, pass through the coils of a speaker.
- These currents, which represent sounds, are always changing in size and direction, like vibrating sound waves.
- The fields of the coil and the permanent magnet are therefore creating magnetic field patterns which are also always changing in strength and direction.
- These fields in turn apply rapidly changing forces to the wires of the coil, which cause the speaker cone to vibrate.
- These vibrations create the sound waves we hear.



▲ Figure 16.6 A loudspeaker transfers energy to create sound.

THE ELECTRIC MOTOR

The electric motor is one of the most important uses of the motor effect. Figure 16.7 shows the most important features of a simple d.c. electric motor.



▲ Figure 16.7 A simple electric motor

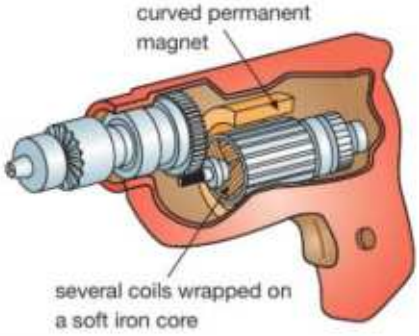
When there is current in the loop of wire, one side of it will experience a force pushing it upwards. The other side will feel a force pushing it downwards, so the loop will begin to rotate (turn).

As the loop reaches the vertical position, its momentum takes it past the vertical. If the rotation is to continue the forces on the wires must now be reversed so that the wire at the top is now pushed down and the bottom one is pushed up.

This can be done easily by using a split ring to connect the loop of wire to the electrical supply. Now each time the loop of wire passes the vertical position, the connections change, the direction of the current changes, and the forces on the different sides of the loop change direction. The loop will rotate continuously.

To increase the rate at which the motor turns we can:

1. increase the number of turns or loops of wire, making a coil
2. increase the strength of the magnetic field
3. increase the current in the loop of wire.



▲ Figure 16.8 A real electric motor

EXTENSION WORK

Although you will not be asked this in your exam it is interesting to know how commercial motors like the one used in this electric drill differ from the simple motor described in Figure 16.7.

- The permanent magnets are replaced with curved electromagnets capable of producing very strong magnetic fields.
- The single loop of wire is replaced with several coils of wire wrapped on the same axis. This makes the motor more powerful and allows it to run more smoothly.
- The coils are wrapped on a soft iron core that has been covered by a thin layer of plastic. This makes the motor more efficient and more powerful.

ELECTROMAGNETIC INDUCTION

Motors use electricity to produce movement. Generators and alternators are machines that use motion to produce electricity. They use a process called electromagnetic induction.

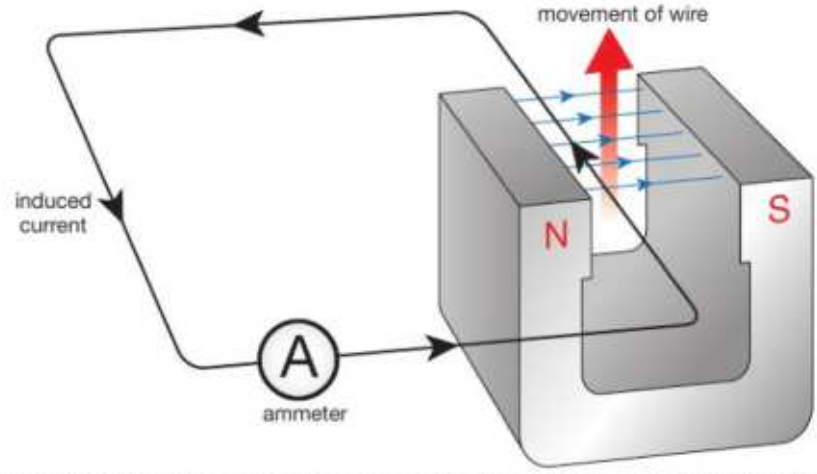


▲ Figure 16.9 Transportable generators are used to produce electricity for the lights and machinery used on roadworks.

The workers shown in Figure 16.9 need electricity for their machines and their lights. Instead of connecting into the mains supply, as we do at home, the workers have their own generator, which produces the electrical energy they need. In fact, the mains supply itself is produced by large generators in power stations. In this next section, you will discover how a generator produces electricity.

DEMONSTRATING ELECTROMAGNETIC INDUCTION

If we move a wire across a magnetic field at right angles, as shown in Figure 16.10, a voltage is induced or generated in the wire. If the wire is part of a complete circuit, there is a current. This event is called electromagnetic induction.

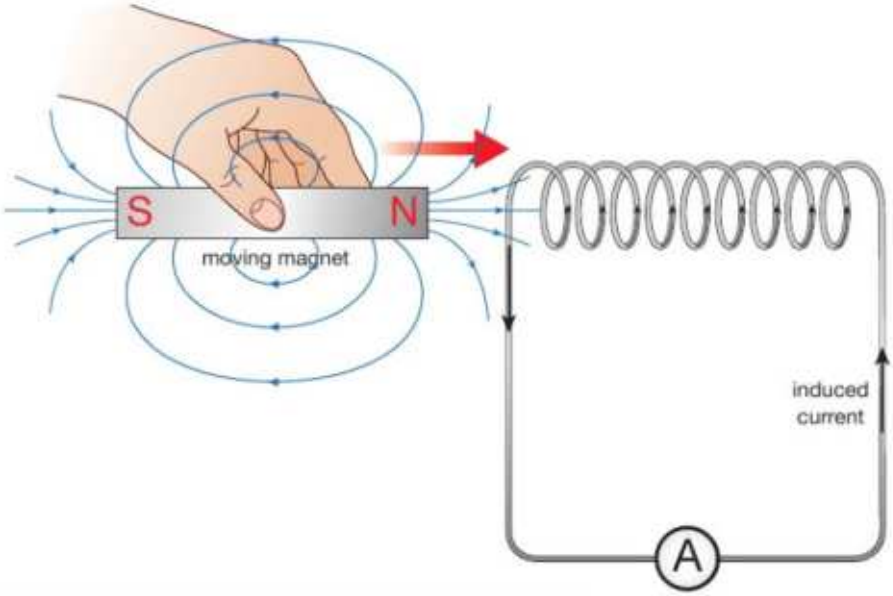


▲ Figure 16.10 When a wire moves across a magnetic field a voltage is generated in the wire.

The size of the induced voltage (and current) can be increased by:

1. moving the wire more quickly
2. using a stronger magnet so that there are more field lines 'cut'
3. wrapping the wire into a coil so that more pieces of wire move through the magnetic field.

We can also generate a voltage and current by pushing a magnet into a coil. In this situation and the previous one (Figure 16.10) we can see that it is the cutting action between the wires and the field lines that generates the voltage. If there is no cutting (that is, the wires and magnets are stationary) no voltage is generated.



▲ Figure 16.11 A magnet moving in a coil will generate electricity.

This experiment also shows us that the size of the induced voltage (and current) can be increased by:

1 moving the magnet more quickly

2 using a stronger magnet

3 using a coil with more turns.

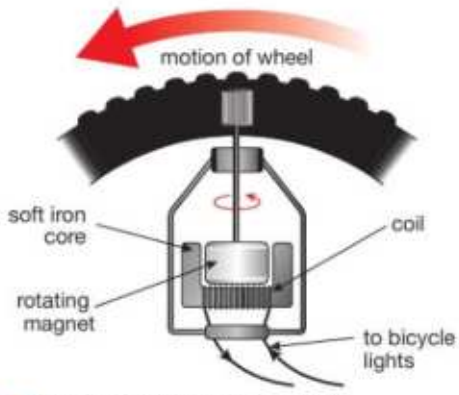
We can summarise all the discoveries from these experiments by saying:

- a voltage is induced when a conductor cuts through magnetic field lines
- a voltage is induced when magnetic field lines cut through a conductor
- the faster the lines are cut the larger the induced voltage.

EXTENSION WORK

It is interesting to note, but not necessary for your exam, that Michael Faraday was the first person to observe how the size of an induced voltage depends upon the rate at which the magnetic lines of flux (field lines) are being cut. He summarised his observations in Faraday's Law of Electromagnetic Induction. This states that:

The size of the induced voltage across the ends of a wire (coil) is directly proportional to the rate at which the magnetic lines of flux are being cut.



▲ Figure 16.12 A dynamo is a simple generator.

GENERATORS

Figure 16.12 shows a small generator or dynamo used to generate electricity for a bicycle light.

As the cyclist pedals, the wheel rotates and makes a small magnet within the dynamo turn around. As this magnet turns, its magnetic field turns too. The field lines cut through the coil inducing a current in it. This current can be used to work the cyclist's lights.



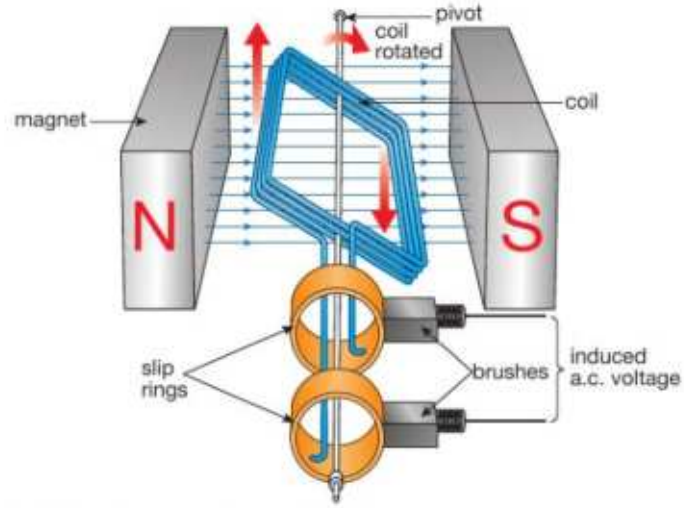
▲ Figure 16.13 This generator produces electricity on an industrial scale.

Figure 16.13 shows a much larger generator used in power stations to generate the mains electricity we use in our homes. In these generators the magnets are stationary and the coils rotate.

The size of the induced voltage is greater than in the bicycle dynamo because these generators **a** use much stronger magnets, **b** have many more turns of wire on the coil, and **c** spin the coil much faster.

LOOKING AHEAD

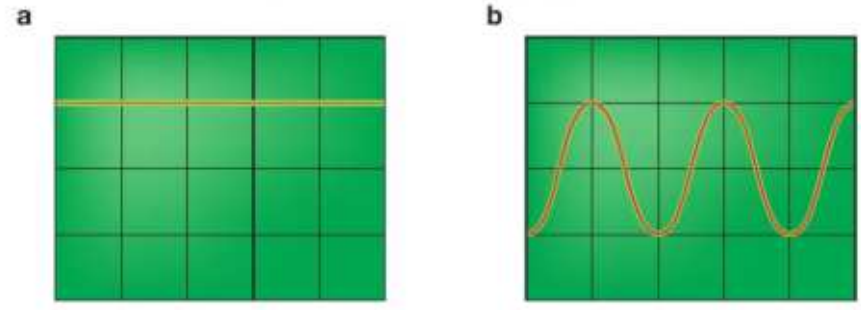
Higher Physics courses are likely to ask you what exactly is happening inside a generator and what is an alternator. The simple description given below will give you some idea of what is required.



▲ Figure 16.14 The alternator produces alternating current.

As the coil rotates, its wires cut through magnetic field lines and a current is induced in them. If we watch just one side of the coil we see that the wire moves up through the field and then down for each turn of the coil. As a result the current is induced first in one direction and then in the opposite direction. This kind of current is called alternating current. A generator that produces alternating current is called an alternator.

The frequency of an alternating current is the number of complete cycles it makes each second. If an alternator coil rotates twice in a second, the frequency of the alternating current it produces is 2 Hz (2 cycles per second). The frequency of the UK mains supply is 50 Hz.



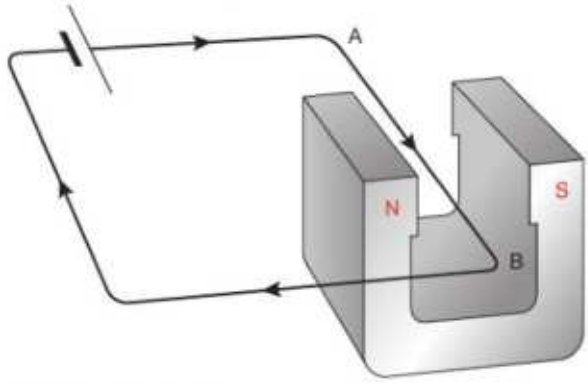
▲ Figure 16.15 **a** In a direct current (d.c) the charge flows in one direction. **b** Alternating currents (a.c.) keep changing direction.

CHAPTER QUESTIONS

More questions on electric motors and electromagnetic induction can be found at the end of Unit 6 on page 654.

SKILLS ANALYSIS, REASONING

1 The diagram below shows a long wire placed between the poles of a magnet.



Describe what happens when:

a there is current in the wire from A to B

b the direction of the current is reversed – that is, from B to A

c with the current from B to A, the poles of the magnet are reversed

d there is a larger current in the wire.

SKILLS INTERPRETATION

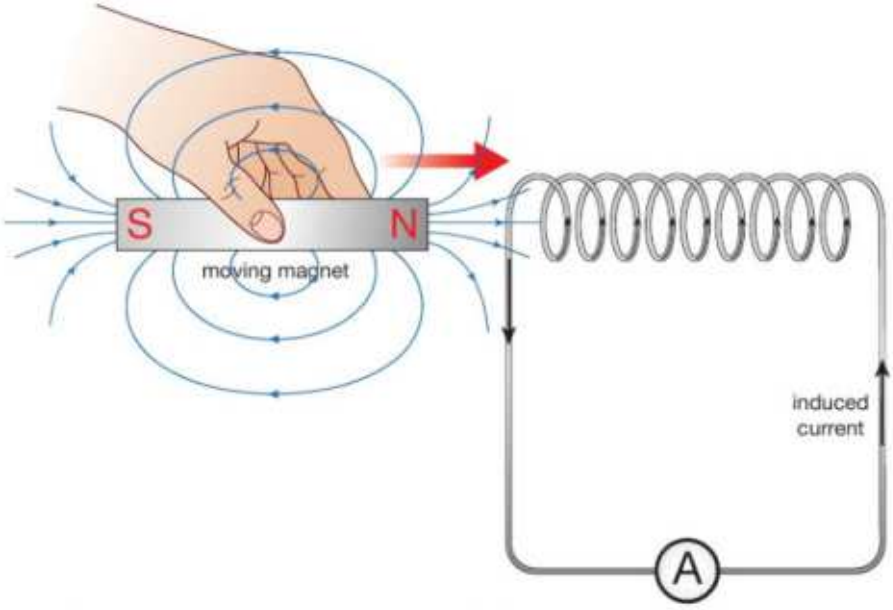
SKILLS CRITICAL THINKING

2 a Draw a simple labelled diagram of a moving-coil loudspeaker.

b Explain how sound waves are made by the speaker when a signal is passed through its coil.

SKILLS REASONING

3 The diagram below shows a bar magnet being pushed into a long coil. A sensitive meter is connected across the coil.



Describe what happens to the meter when:

a the magnet is pushed into the coil quickly

b the magnet is held stationary inside the coil

c the magnet is pulled out of the coil slowly

d the magnet is held stationary and the coil is moved towards it.

UNIT QUESTIONS

SKILLS CRITICAL THINKING

1

a Which of these objects is made from a magnetic material?

A a rubber band

B a piece of paper

C a steel nail

D a plastic ruler **(1)**

b In which of these situations will you see attraction?

A The north poles of two magnets are placed close together.

B A wooden rod is placed close to a strong magnet.

C The south poles of two magnets are placed close together.

D The north pole of one magnet is placed close to the south pole of another magnet. **(1)**

c Which of these statements is true for a magnetically hard material?

A They are difficult to bend.

B They are used to make permanent magnets.

C They are electrical insulators.

D They are used in electromagnets. **(1)**

(Total 3 marks)

2

Copy and complete the following passage, filling in the blanks.

A wire carrying an electric current experiences a _____ when it is in a _____ field. This effect can be used in _____ and electric _____.

If a wire is moved through a magnetic field, or the magnetic field near a _____ of wire changes, a current can be _____ in the wire. This effect is used in _____ and _____.

(Total 8 marks)

SKILLS REASONING

3

a Explain how a bicycle dynamo generates current. **(3)**

b Why does the dynamo produce no current when the cyclist has stopped? **(1)**

SKILLS CRITICAL THINKING

c What is an alternator? **(1)**

SKILLS INTERPRETATION, CRITICAL THINKING

d Explain using diagrams the difference between a.c. and d.c. currents. **(3)**

SKILLS CRITICAL THINKING

e Explain what is meant by this statement: 'The mains supply in the UK has a frequency of 50 Hz.' **(2)**

(Total 10 marks)

SKILLS CREATIVITY, REASONING

8th

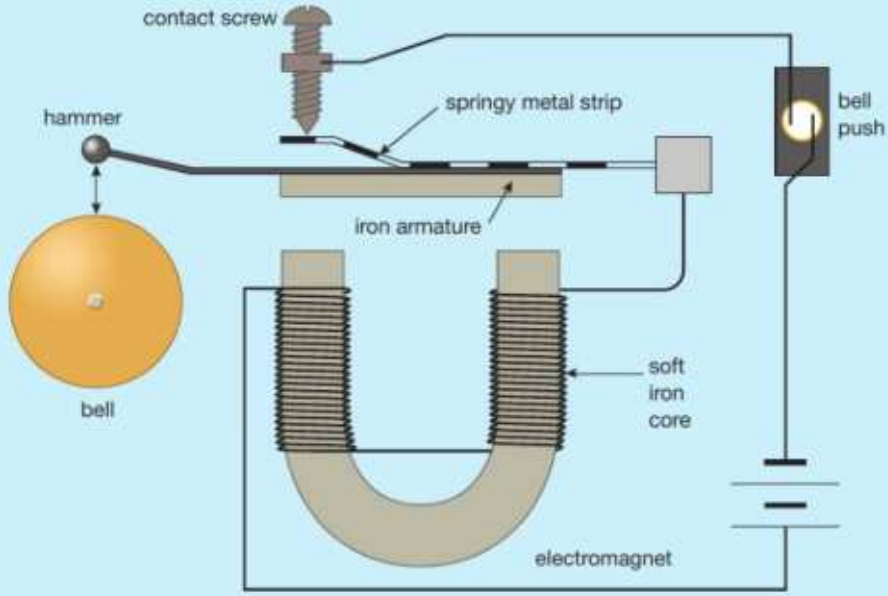
4 A keen cyclist builds his own dynamo to generate electricity for his lights. Unfortunately, when he tries it out the lights are not bright enough. Suggest two changes he could make to his dynamo to generate more electricity. Is there a third solution to his problem?

(Total 3 marks)

SKILLS REASONING

7th

5 The diagram below shows the circuit for an electric bell.



a Explain in your own words why the bell will not work if the electromagnet is replaced with a permanent magnet. **(2)**

b Explain why the core of the electromagnet used in an electric bell must not be made from steel. **(3)**

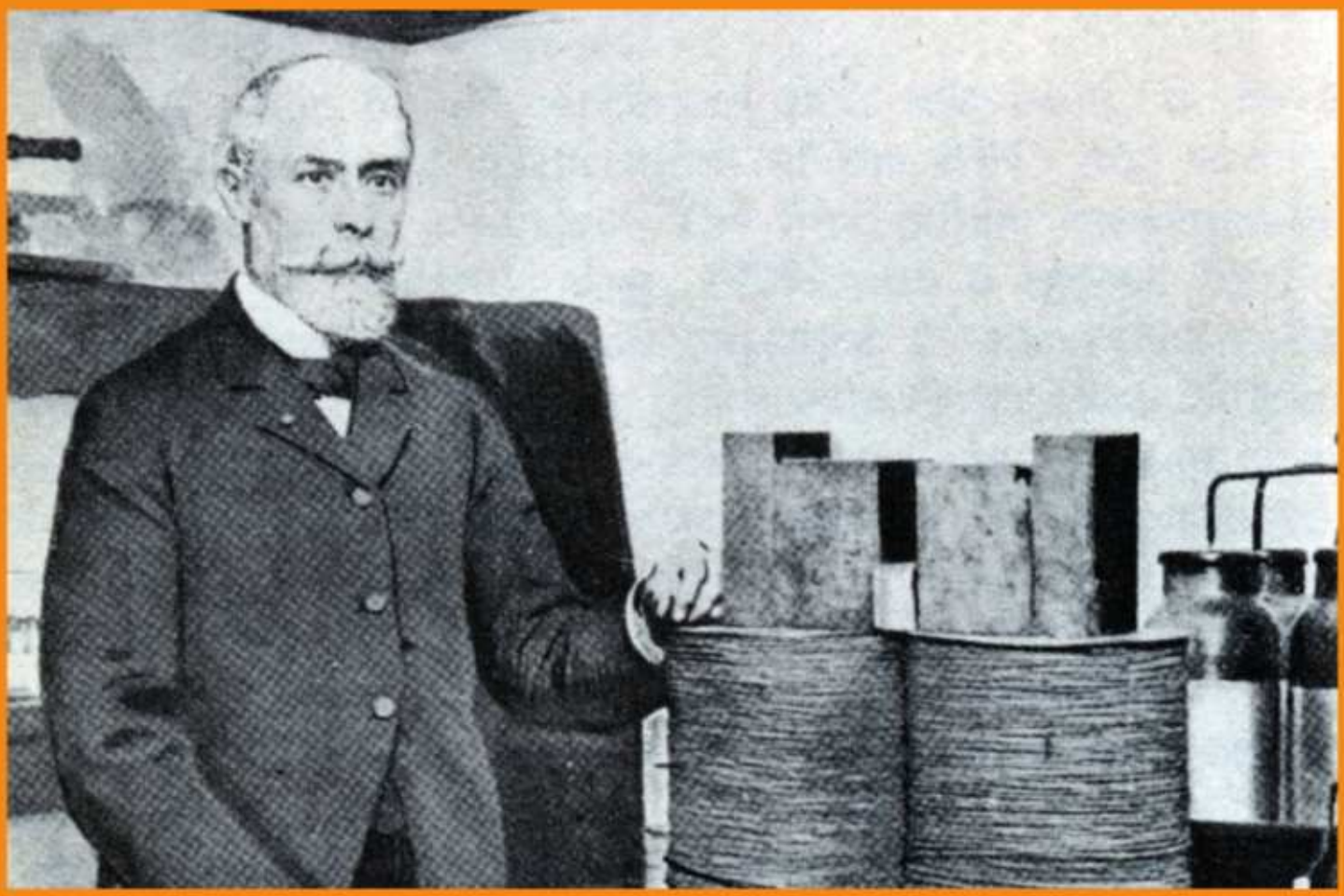
(Total 5 marks)

ATOMS AND RADIOACTIVITY 657 | RADIATION AND HALF-LIFE 669 | APPLICATIONS OF RADIOACTIVITY 677
FISSION AND FUSION 686

PHYSICS UNIT 7 RADIOACTIVITY AND PARTICLES

Henri Becquerel was a scientist whose pioneering work led to the discovery of radioactivity and set other scientists on a path of research that continues today.

Using radioactivity has enabled us to learn about the structure of matter, to develop new sources of energy and to understand a new force of nature: nuclear forces that bind matter together and control the processes that fuel stars and formed all the elements that we and the Universe are made of.



17 ATOMS AND RADIOACTIVITY

Atoms are made up of sub-atomic particles called neutrons, protons and electrons. It is the numbers of these particles that give each element its unique properties. In this chapter you will find out how atoms can break up and become transformed into different elements, and about the different types of radiation they give out.

LEARNING OBJECTIVES

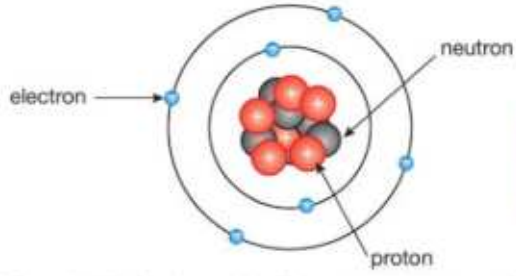
- Describe the structure of an atom in terms of protons, neutrons and electrons and use symbols such as $^{14}_{6}C$ to describe particular nuclei
- Know the terms atomic (proton) number, mass (nucleon) number and isotope
- Know that alpha (α) particles, beta (β^-) particles, and gamma (γ) rays are ionising radiations emitted from unstable nuclei in a random process
- Describe the nature of alpha (α) particles, beta (β^-) particles, and gamma (γ) rays, and recall that they may be distinguished in terms of penetrating power and ability to ionise
- Investigate the penetration powers of different types of radiation using either radioactive sources or simulations
- Describe the effects on the atomic and mass numbers of a nucleus of the emission of each of the four main types of radiation (alpha, beta, gamma and neutron radiation)
- Understand how to balance nuclear equations in terms of mass and charge

UNITS

In this section you will need to use becquerel (Bq) as the unit of activity of a radioactive source, centimetre (cm) as the unit of length, and minute (min) and second (s) as the units of time.

ELECTRONS, PROTONS AND NEUTRONS

Atoms are made up of electrons, protons and neutrons. Figure 17.1 shows a simple model of how these particles are arranged.



▲ Figure 17.1 A simple model with protons and neutrons in the nucleus of the atom and electrons in orbits around the outside

The electron is a very small particle with very little mass. It has a negative electric charge. Electrons orbit the nucleus of the atom. The nucleus is very small compared to the size of the atom itself. The diameter of the nucleus is about 10 000 times smaller than the diameter of the atom. If the nucleus of an atom were enlarged to the size of a full stop on this page, the atom would have a diameter of around 2.5 metres.

The nucleus is made up of protons and neutrons. Protons and neutrons have almost exactly the same mass. Protons and neutrons are nearly 2000 times heavier than electrons. Protons carry positive electric charge but neutrons, as the name suggests, are electrically neutral or uncharged. The amount of charge on a proton is equal to that on an electron but opposite in sign.

EXTENSION WORK

The actual mass of an electron is 9.1×10^{-31} kg and its actual charge is -1.6×10^{-19} C. The table shows the approximate relative masses of the particles and the relative amount of charge they carry. The mass in atomic mass units is discussed below.

The properties of these three atomic particles are summarised in the table below. Protons and neutrons are also called nucleons because they are found in the nucleus of the atom.

Atomic particle	Relative mass of particle	Relative charge of particle
electron	1	–1
proton	2000	+1
neutron	2000	0

THE ATOM

The nucleus of an atom is surrounded by electrons. We sometimes think of electrons as orbiting the nucleus in a way similar to the planets orbiting the Sun. It is more accurate to think of the electrons as moving rapidly around the nucleus in a cloud or shell.

An atom is electrically neutral. This is because the number of positive charges carried by the protons in its nucleus is balanced by the number of negative charges on the electrons in the electron 'cloud' around the nucleus.

ATOMIC NUMBER, Z

The chemical behaviour and properties of a particular element depend upon how the atoms combine with other atoms. This is determined by the number of electrons in the atom. Although atoms may gain or lose electrons, sometimes quite easily, the number of protons in atoms of a particular element is always the same. The atomic number of an element tells us how many protons each of its atoms contains. For example, carbon has six protons in its nucleus – the atomic number of carbon is, therefore, 6. The symbol we use for atomic number is Z. Each element has its own unique atomic number. The atomic number is sometimes called the proton number.

ATOMIC MASS, A

The total number of protons and neutrons in the nucleus of an atom determines its atomic mass. The mass of the electrons that make up an atom is tiny and can usually be ignored. The mass of a proton is approximately 1.7×10^{-27} kg. To save writing this down we usually refer to the mass of an atom by its mass number or nucleon number. This number is the total number of protons and neutrons in the atom. The mass number of an element is given the symbol A.

ATOMIC NOTATION – THE RECIPE FOR AN ATOM

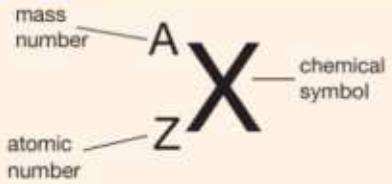
Each particular type of atom will have its own atomic number, which identifies the element, and a mass number that depends on the total number of nucleons, or particles, in the nucleus. Figure 17.2 shows the way we represent an atom of an element whose chemical symbol is X, showing the atomic number and the mass number.

So, using this notation, an atom of oxygen is represented by:

$^{16}_{8}O$

The chemical symbol for oxygen is O. The atomic number is 8 – this tells us that the nucleus contains eight protons. The mass number is 16, so there are 16 nucleons (protons and neutrons) in the nucleus. Since eight of these are protons, the remaining eight must be neutrons. The atom is electrically neutral overall, so the +8 charge of the nucleus is balanced by the eight orbiting electrons, each with charge –1.

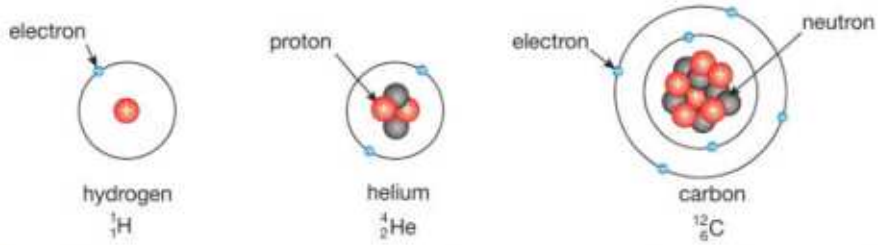
KEY POINT



▲ Figure 17.2 Atomic notation

mass number, A = number of neutrons + number of protons, Z
= number of nucleons

so
number of neutrons = number of nucleons – number of protons
= A – Z



▲ Figure 17.3 The hydrogen atom has one proton in its nucleus and no neutrons, so the mass number A = 1 + 0 = 1. As it has one proton, its atomic number, Z = 1. For helium, A = 4 (2 protons + 2 neutrons) and Z = 2 (2 protons). For carbon, A = 12 (6 protons + 6 neutrons) while Z = 6 (6 protons).

Figure 17.3 shows some examples of the use of this notation for hydrogen, helium and carbon, together with a simple indication of the structure of an atom of each of these **elements**. In each case the number of orbiting electrons is equal to the number of protons in the nucleus, so the atoms are electrically neutral.

ISOTOPES

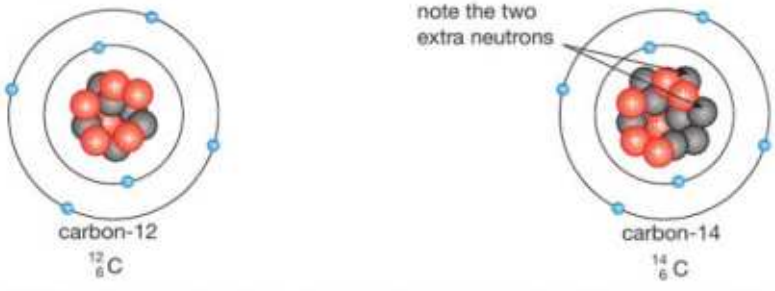
The number of protons in an atom identifies the element. The chemical behaviour of an element depends on the number of electrons it has and, as we have seen, this always balances the number of protons in the nucleus. However, the number of neutrons in the nucleus can vary slightly. Atoms of an element with different numbers of neutrons are called isotopes of the element. The number of neutrons in a nucleus affects the mass of the atom. Different isotopes of an element will all have the same atomic number, Z, but different mass numbers, A. Figures 17.4 and 17.5 show some examples of isotopes.



▲ Figure 17.4 Isotopes of hydrogen – they all have the same atomic number, 1, and the same chemical symbol, H.

EXTENSION WORK

Hydrogen-2 is also called heavy hydrogen or deuterium. Hydrogen-3 is called tritium.



▲ Figure 17.5 Two isotopes of carbon – they are referred to as carbon-12 and carbon-14 to distinguish between them.

THE STABILITY OF ISOTOPES

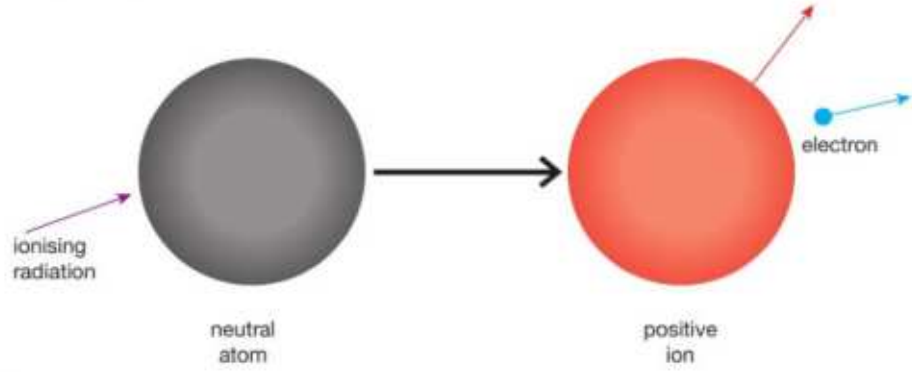
Isotopes of an element have different physical properties from other isotopes of the same element. One obvious difference is the mass. Another difference is the stability of the nucleus.

The protons are held in the nucleus by the nuclear force. This force is very strong and acts over a very small distance. It is strong enough to hold the nucleus together against the electric force repelling the protons away from

each other. (Remember that protons carry positive charge and like charges repel.) The presence of neutrons in the nucleus affects the balance between these forces. Too many or too few neutrons will make the nucleus **unstable**. An unstable nucleus will eventually decay. When the nucleus of an atom decays it gives out energy and may also give out alpha or beta particles.

IONISING RADIATION

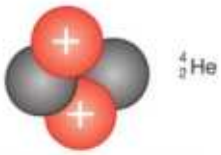
When unstable nuclei decay they give out ionising radiation. Ionising radiation causes atoms to gain or lose electric charge, forming ions. Unstable nuclei decay at random. This means that it is not possible to predict which unstable nucleus in a piece of **radioactive** material will decay, or when decay will happen. We shall see that we can make measurements that will enable us to predict the probability that a certain proportion of a radioactive material will decay in a given time.



▲ Figure 17.6 When a neutral atom (or molecule) is hit by ionising radiation it loses an electron and becomes a positively charged ion.

There are three basic types of ionising radiation. They are: alpha (α), beta (β) and gamma (γ) radiation.

ALPHA (α) RADIATION



▲ Figure 17.7 An alpha particle (α particle)

EXTENSION WORK

Nucleons have roughly 2000 times the mass of an electron, and alpha particles are made up of four nucleons, so an alpha particle has 8000 times the mass of a beta particle.

Alpha radiation consists of fast-moving particles that are thrown out of unstable nuclei when they decay. These are called alpha particles. Alpha particles are helium nuclei – helium atoms without their orbiting electrons. Figure 17.7 shows an alpha particle and the notation that is used to denote it in equations.

Alpha particles have a relatively large mass. They are made up of four nucleons and so have a mass number of 4. They are also charged because of the two protons that they carry. The **relative charge** of an alpha particle is +2.

Alpha particles have a short range. The range of ionising radiation is the distance it can travel through matter. Alpha particles can only travel a few centimetres in air and cannot penetrate more than a few millimetres of paper. They have a limited range because they interact with atoms along their paths, causing ions to form. This means that they rapidly give up the energy that they had when they were ejected from the unstable nucleus.

BETA RADIATION (β^- AND β^+)

Beta minus particles (β^-) are very fast-moving electrons that are ejected by a decaying nucleus. The nucleus of an atom contains protons and neutrons, so where does the electron come from? The stability of a nucleus depends on the proportion of protons and neutrons it contains. The result of radioactive decay is to change the balance of protons and neutrons in the nucleus to make it

EXTENSION WORK

Antimatter will not be examined, but for all the particles that exist in ordinary matter there exists an antimatter particle. The positron is the antimatter equivalent of an electron. You will not be asked about neutrinos or antineutrinos either.

more stable. Beta minus decay involves a neutron in the nucleus splitting into a proton and an electron (an antineutrino is also emitted). The proton remains in the nucleus and the electron is ejected at high speed as a beta minus particle.

EXTENSION WORK

Sometimes a proton will decay into a neutron by emitting a beta plus particle (β^+). A beta plus particle is an antielectron, a particle with the same mass as an electron but with positive charge. The antielectron is called a positron.

Beta particles are very light – they have only 0.000 125 times the mass of an alpha particle. The relative charge of a β^- is –1 and the relative charge of a β^+ is +1.

Beta particles interact with matter in their paths less frequently than alpha particles. This is because they are smaller and carry less charge. This means that beta particles have a greater range than alpha particles. Beta particles can travel long distances through air, pass through paper easily and are only absorbed by denser materials like aluminium. A millimetre or two of aluminium foil will stop all but the most energetic beta particles.

GAMMA RAYS (γ)

EXTENSION WORK

Gamma radiation is emitted in 'packets' of energy called photons.

Gamma rays are electromagnetic waves (see page 568) with very short wavelengths. As they are waves, they have no mass and no charge. They are weakly ionising and interact only occasionally with atoms in their paths. They are extremely penetrating and pass through all but the very densest materials with ease. It takes several centimetres thickness of lead, or a metre or so of concrete, to stop gamma radiation.

NEUTRON RADIATION

Neutrons are emitted by radioactive material. They have roughly the same mass as a proton but have no electric charge. The symbol used for a neutron in radioactive decay equations is:

$$^{1}_{0}n$$

If a neutron is emitted by a nucleus its mass number (A) goes down by 1 but the atomic number (Z) is unchanged. If a neutron is absorbed by a nucleus its mass number (A) goes up by 1 but the atomic number (Z) is unchanged.

EXTENSION WORK

As neutrons cause other atoms to emit radiation they must be screened. This is done using materials that have a lot of light atoms like hydrogen. Concrete and water are used to prevent neutrons escaping from nuclear reactors.

KEY POINT

As neutrons are not electrically charged they do not directly cause ionisation. They are absorbed by nuclei of other atoms and can cause them to become radioactive. The radioactive nuclei formed in this way will then decay emitting ionising radiation. Neutrons are the only type of radiation to cause other atoms to become radioactive. We shall see later (Chapter 20) that neutron radiation plays an important part in the process of fission used in nuclear reactors.

SUMMARY OF THE PROPERTIES OF IONISING RADIATION

We have said that ionising radiation causes uncharged atoms to lose electrons. An atom that has lost (or gained) electrons has an overall charge. It is called an ion. The three types of radioactive **emission** can all form ions.

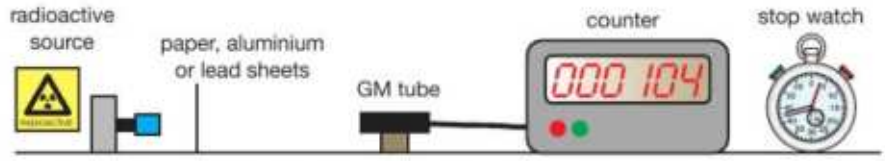
As ionising radiation passes through matter, its energy is absorbed. This means that radiation can only penetrate matter up to a certain thickness. This depends on the type of radiation and the density of the material that it is passing through.

The ionising and penetrating powers of alpha, beta and gamma radiation are compared in the table on page 662. Note that the ranges given in the table are typical but they do depend on the energy of the radiation. For example, more energetic alpha particles will have a greater range than those with lower energy.

Radiation	Ionising power	Penetrating power	Example of range in air	Radiation stopped by
alpha, α	strong	weak	5–8 cm	paper
beta, β	medium	medium	500–1000 cm	thin aluminium
gamma, γ	weak	strong	virtually infinite	thick lead sheet

ACTIVITY 1

▼ PRACTICAL: INVESTIGATE THE PENETRATING POWERS OF DIFFERENT KINDS OF RADIATION



▲ Figure 17.8 Measuring the penetrating power of different types of radiation

Radioactive sources must be stored in lead-lined boxes and kept in a metal cupboard with a radiation warning label. The source must be handled with tongs away from the body. (See Chapter 19 page 683 for more details of safe practice with radioactive materials.)

Before the source is removed from its storage container, measure the background radiation count by connecting a Geiger–Müller (GM) tube to a counter. Write down the number of counts after 5 minutes. Repeat this three times and find the average background radiation count.

Take a source of alpha radiation and set it up at a measured distance (between 2 and 4 cm) from the GM tube.

Measure the counts detected in a 5 minute period. Repeat the count with a sheet of thick paper in front of the source. You should find that the counts have dropped to the background radiation count. This shows that alpha radiation does not pass through paper.

Now replace the alpha source with a beta source. After measuring the new count for 5 minutes place thin sheets of aluminium between the source and detector. When the thickness of the aluminium sheet is 1–2 mm thick you will find that the count has dropped to the background radiation level. This shows that beta radiation is blocked by just a few millimetres of aluminium.

Finally carry out the same steps using a gamma radiation source. Now you will find that gamma radiation is only blocked when a few centimetres of lead are placed between the source and the detector.

Safety note: All work with radioactive sources must be closely supervised by qualified science staff and no sources must be touched or pointed towards any part of the body. Source usage must be logged and they must be returned to their secure storage immediately after use. In the UK, students under 16 years are not permitted to handle sources; over 16, they are allowed to do this with close supervision.

KEY POINT

The Geiger–Müller (GM) tube is a detector of radiation. It is described in the next chapter.

As we said earlier, an unstable atom, or strictly speaking its nucleus, will decay by emitting radiation. If the decay process involves the nucleus ejecting either an alpha or a beta particle, the atomic number will change. This means that alpha or beta decay causes the original element to transform into a different element.

ALPHA (α) DECAY

Here is an example of alpha decay:

$$^{222}_{88}\text{Ra} \rightarrow {}^{218}_{86}\text{Ra} + {}^{4}_{2}\text{He} + \text{energy}$$

radium atom → radon atom + α particle + energy

The radioactive isotope radium-222 decays to the element radon by the emission of an alpha particle. The alpha particle is sometimes represented by the Greek letter α. Radon is a radioactive gas that also decays by emitting an alpha particle. Note that the atomic number for radon, 86, is two less than the atomic number for radium.

This is a balanced equation:

- The total of the A numbers on each side of the equation is the same. (Remember that A is the total number of protons and neutrons.)
- The total of the Z numbers on each side of the equation is the same. (Remember that the Z number tells us the number of protons in the nucleus – the number of positively charged particles.)

REMINDER

A is the mass number of the element and Z is the atomic number. The letters W and Y are not the symbols of any particular elements as this is the general equation.

The general form of the alpha decay equation is:

$$^{A}_{Z}\text{Y} \rightarrow {}^{A-4}_{Z-2}\text{W} + {}^{4}_{2}\text{He} + \text{energy}$$

alpha particle, α

KEY POINT

It is worth pointing out that the mass number refers to the number of nuclear particles, or nucleons, involved in the transformation – not the exact mass. Mass is not conserved in nuclear transformations, as some of it is transformed into energy.

In alpha decay, element Y is transformed into element W by the emission of an alpha particle. Element W is two places before element Y in the Periodic Table. The alpha particle, a helium nucleus, carries away four nucleons, which reduces the mass number (A) by four. Two of these nucleons are protons so the atomic number of the new element is two less than the original element, Z – 2. Notice that the mass number and the atomic number are conserved through this equation – that is, the total numbers of nucleons and protons on each side of the equation are the same.

EXAMPLE 1

Complete the following nuclear equation which shows the decay of uranium-238 to the element thorium by alpha decay (emitting an alpha particle).

$$^{238}_{92}\text{U} \rightarrow {}^{?}_{?}\text{Th} \rightarrow {}^{4}_{2}\text{He}$$

The atomic mass numbers (A) on both sides of the equation must add up to the same, so the atomic mass for thorium must be 234 (238 = 234 + 4).

The atomic numbers (Z) on both sides of the equation must add up to the same, so the atomic mass for thorium must be 90 (92 = 90 + 2). So the answer is:

$$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} \rightarrow {}^{4}_{2}\text{He}$$

KEY POINT

A complete Periodic Table is shown in Appendix A on page 708. The numbers shown in the top left corner are the atomic numbers of the elements – the Z numbers in the nuclear equations. Remember that the Z numbers tell us the number of protons in the nucleus of an element. Some periodic tables show the atomic mass too but as elements have a number of different isotopes the mass numbers will be an average for the different isotopes.

Figure 17.9 shows the effect of alpha particle decay. Losing an alpha particle from the nucleus of a uranium atom turns it into thorium, two places back in the Periodic Table.

Ac	Th	Pa	U	Np
Actinium	Thorium	Protactinium	Uranium	Neptunium
89	90	91	92	93

▲ Figure 17.9 A part of the Periodic Table of elements

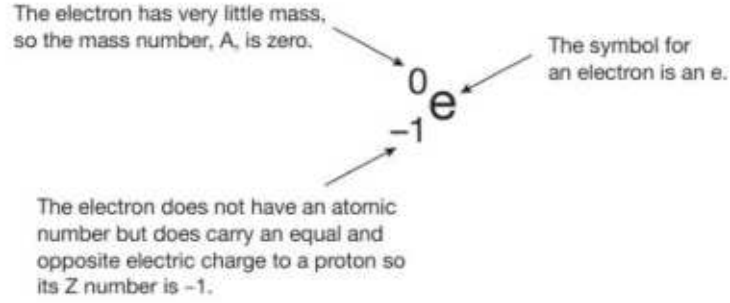
BETA (β^-) DECAY

Here is an example of beta minus decay:

$$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e + \text{energy}$$

carbon-14 atom → nitrogen-14 atom + beta particle, β^- + energy (also an antineutrino)

The radioactive isotope of carbon, carbon-14, decays to form the stable isotope of the gas nitrogen, by emitting a beta particle. Remember that the beta minus particle is formed when a neutron splits to form a proton and an electron. Figure 17.10 shows the standard atomic notation for a beta particle (β^-).



▲ Figure 17.10 A beta minus particle

The general form of the beta minus decay equation is:

$$^{A}_{Z}X \rightarrow ^{A}_{Z+1}Y + ^{0}_{-1}e + \text{energy}$$

beta minus particle, β^-

In β^- decay, element X is transformed into element Y by the emission of a beta minus particle. Element Y is the next element in the Periodic Table after element X. The beta particle, an electron, has practically no mass so the mass number, A, is the same in X and Y. As the β^- particle has a charge of −1, the atomic number of the new element is increased to Z + 1. Again the mass number and the atomic number are conserved through this equation.

BETA (β^+) DECAY

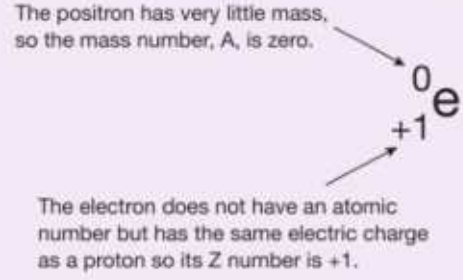
EXTENSION WORK

You will not be asked about β^+ decay but the example here is included to show that the atomic mass numbers (A) and the atomic numbers (Z) on each side of the decay equation must balance. Here is an example of beta plus decay:

$$^{22}_{11}Na \rightarrow ^{22}_{10}Ne + ^{0}_{+1}e + \text{energy}$$

sodium-22 atom → neon-22 atom + beta particle, β^+ + energy (also a neutrino)

The radioactive isotope of sodium (Na), sodium-22, decays to form the stable isotope of the gas neon (Ne), by emitting a beta plus particle. Remember that the beta plus particle is formed when a proton splits to form a neutron and a positron. Figure 17.11 shows the standard atomic notation for a beta particle (β^+).



▲ Figure 17.11 A beta plus particle

The general form of the beta plus decay equation is:

$$^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e + \text{energy}$$

beta plus particle, β^+

In β^+ decay, element X is transformed into element Y by the emission of a beta plus particle. Element Y is the element in the Periodic Table that comes before element X. The beta plus particle, a positron, has practically no mass so the mass number, A, is the same in X and Y. As this beta particle has a charge of +1, the atomic number of the new element is decreased to Z – 1.

EXAMPLE 2

An isotope of caesium $^{137}_{55}Cs$ decays by emitting an electron (β^-) and forms an atom of barium (Ba). Write a balanced nuclear equation for this decay.

$$^{137}_{55}Cs \rightarrow {}^{?}_{?}Ba + {}^{0}_{-1}e + \text{energy}$$

An electron has practically no mass so the mass number does not change. The emission of an electron happens when a neutron becomes a proton and an electron, so the atomic number increases by one. The barium isotope formed is therefore $^{137}_{56}Ba$ and the completed equation is:

$$^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + {}^{0}_{-1}e + \text{energy}$$

When an element decays by emitting an electron it changes to the element with the next higher atomic number. You can check this by looking at the Periodic Table on page 708.

REMINDER

You will not be asked questions involving positrons in the exam.

EXAMPLE 3

An isotope of magnesium $^{23}_{12}Mg$ decays by emitting a positron (β^+) and forms an atom of sodium (Na). Write a balanced nuclear equation for this decay.

$$^{23}_{12}Mg \rightarrow {}^{?}_{?}Na + {}^{0}_{+1}e$$

A positron has practically no mass so the mass number does not change. The emission of a positron happens when a proton in the nucleus becomes a neutron and a positron, so the atomic number decreases by one. The sodium isotope formed is therefore $^{23}_{11}Na$ and the completed equation is:

$$^{23}_{12}Cs \rightarrow {}^{23}_{11}Na + {}^{0}_{+1}e$$

When an element decays by emitting a positron it changes to the element with the next lower atomic number. You can check this by looking at the Periodic Table on page 708.

NEUTRON DECAY

Here is an example of neutron decay:

$$^{5}_{2}He \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$$

helium-5 atom → helium-4 atom + neutron

As a neutron has no electric charge, the total positive charge is unchanged by the emission of a neutron – the Z number is 2 before and after the decay. The total number of particles (protons and neutrons) in the nucleus of the helium atom has decreased by 1 because of emission of the neutron.

EXAMPLE 4

An isotope of beryllium, $^{13}_{4}Be$, decays by emitting a neutron. Write a balanced nuclear equation for this transformation.

Write down what you know:

$$^{13}_{4}Be \rightarrow {}^{?}_{?}? + {}^{1}_{0}n$$

The emission of a neutron has no effect on the charge so the atomic number (Z) is unchanged at 4. Each element has its own atomic number so the element in this decay is unchanged – it is still an isotope of beryllium. The loss of a neutron from the beryllium nucleus means that the atomic mass decreases by one. The completed equation is:

$$^{13}_{4}Be \rightarrow {}^{12}_{4}Be + {}^{1}_{0}n$$

GAMMA (γ) DECAY

Gamma radiation is high-energy electromagnetic radiation (see page 568). After an unstable nucleus has emitted an alpha or beta particle it sometimes has surplus energy. It emits this energy as gamma radiation. Gamma rays are pure energy, so they do not have any mass or charge. When a nucleus emits a gamma ray there is no change to either the atomic number or the mass number of the nucleus.

LOOKING AHEAD



▲ Figure 17.12 Inside the Large Hadron Collider

Understanding the particles that make up all matter in the Universe, how they interact and the forces involved holding matter together remains a major area of research for physicists. This is an introduction to what has been called the 'particle zoo'. Large particle accelerators, like the Large Hadron Collider (LHC) on the Swiss/French border, have identified many new particles. Energy turned into matter! Research has recognised patterns in these particles and we now have a model that explains many complex nuclear processes – some of which have increased our understanding of how the Universe was formed.

We also understand how matter can be transformed into energy and the amazing amount of energy that results, revealed by Albert Einstein in his famous equation:

$$E = mc^2$$

CHAPTER QUESTIONS

More questions on the structure of the atom can be found at the end of Unit 7 on page 691.

SKILLS CRITICAL THINKING

1 Copy and complete the table below. Identify the particles and complete the missing data.

Atomic particle	Relative mass of particle	Relative charge of particle
	1	–1
		+1
	2000	0

2 Identify the following atomic particles from their descriptions:

a an uncharged nucleon

b the particle with the least mass

c the particle with the same mass as a neutron

d the particle with the same amount of charge as an electron

e a particle that is negatively charged.

3 Explain the following terms used to describe the structure of an atom:

a atomic number

b mass number.

4 Copy and complete the table below, describing the structures of the different atoms in terms of numbers of protons, neutrons and electrons.

	$^{3}_{2}He$	$^{13}_{6}C$	$^{23}_{11}N$
protons			
neutrons			
electrons			

5 Copy and complete the following sentences:

a An alpha particle consists of four _____. Two of these are _____ and two are _____. An alpha particle carries a charge of _____.

b A beta minus particle is a fast-moving _____ that is emitted from the nucleus. It is created when a _____ in the nucleus decays to form a _____ and the beta particle.

c A third type of ionising radiation has no mass. It is called _____ radiation. This type of radiation is a type of wave with a very _____ wavelength.

d Gamma radiation is part of the _____ spectrum.

SKILLS PROBLEM SOLVING

6 The following nuclear equation showing beta plus decay:

$$^{1}_{1}p \rightarrow {}^{1}_{0}\square + {}^{\square}_{\square}e$$

a From the following list of particles:

A electron B neutron C proton D alpha particle

i State which is the particle on the left of this balanced equation.

ii State which is the first of the terms on the right of this equation.

b The second term on the right of this equation is a positron – the antiparticle of an electron. Copy and complete the above equation filling in the empty boxes shown.

SKILLS ANALYSIS, REASONING

7 A certain radioactive source emits different types of radiation. The sample is tested using a Geiger counter. When a piece of card is placed between the source and the counter, there is a noticeable drop in the radiation. When a thin sheet of aluminium is added to the card between the source and the counter, the count rate is unchanged. A thick block of lead, however, causes the count to fall to the background level.

What type (or types) of ionising radiation is the source emitting? Explain your answer carefully.

HINT

Look at the table on page 662.

SKILLS PROBLEM SOLVING

8 a The nuclear equation below shows the decay of thorium. Copy and complete the equation by providing the missing numbers.

$$^{234}_{90}\text{Th} \rightarrow {}^{\square}_{\square}\text{Pa} + {}^{0}_{-1}\text{e}$$

SKILLS CRITICAL THINKING

b What type of decay is taking place in this transformation?

SKILLS PROBLEM SOLVING

c The nuclear equation below shows the decay of polonium. Copy and complete the equation by providing the missing numbers and letters.

$$^{216}_{\square}\text{Po} \rightarrow {}^{\square}_{82}\text{Pb} + {}^{4}_{2}\square$$

SKILLS CRITICAL THINKING

d What type of decay is taking place in this transformation?

18 RADIATION AND HALF-LIFE

In this chapter you will learn about ways of detecting radiation, and where some of the radiation around us comes from. You will also learn why we use a value called half-life to describe the activity of radioactive isotopes.

LEARNING OBJECTIVES

- Know that photographic film or a Geiger–Müller detector can detect ionising radiation
- Explain the sources of background (ionising) radiation from Earth and space
- Know that the activity of a radioactive source decreases over time and is measured in becquerels
- Know the definition of the term half-life and understand that it is different for different radioactive isotopes
- Use the concept of the half-life to carry out simple calculations on activity, including graphical methods

DETECTING IONISING RADIATION

USING PHOTOGRAPHIC FILM

Wilhelm Röntgen (Figure 18.1a) discovered x-rays in 1895. Henri Becquerel (Figure 18.1b) believed that uranium emitted x-rays after being exposed to sunlight. To test this idea he placed some wrapped, unused photographic plates in a drawer with some samples of uranium **ore** on top of them. He found a strong image of the ore on the plates when he developed them. He later realised that this was due to a new type of ionising radiation. He had discovered radioactivity.

The unit of radioactivity is named after Becquerel. The becquerel (Bq) is a measure of how many unstable nuclei are disintegrating (breaking up) per second – one becquerel means a rate of one disintegration per second. The becquerel is a very small unit. More practical units are the kBq (an average of 1000 disintegrations per second) and the MBq (an average of 1 000 000 disintegrations per second).

Photographic film can still be used to detect radioactivity. Some scientists who work with radioactive materials wear a piece of photographic film in a badge. If the film becomes fogged (unclear) it shows that the scientist has been exposed to a certain amount of radiation. These badges are checked regularly to ensure that scientists are not exposed to too much ionising radiation.

a



b

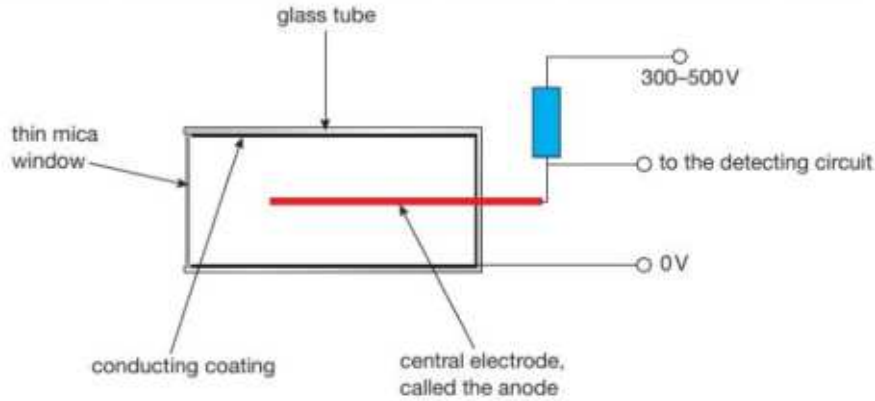


▲ Figure 18.1 **a** Wilhelm Röntgen (1845–1923), **b** Henri Becquerel (1852–1908). Nobel prize winners in 1901 and 1903

THE GEIGER–MÜLLER (GM) TUBE

Figure 18.2 shows the basic construction of a Geiger–Müller (GM) tube. It is a glass tube with an electrically conducting surface on the inside. The tube has a thin window made of mica (a naturally occurring mineral that can be split into thin sheets). The tube contains a special mixture of gases at very low pressure. In the middle of the tube, electrically insulated from the conducting surface, there is an **electrode**. This electrode is connected, via a high-value resistor, to a high-voltage supply, typically 300–500 V.

When ionising radiation enters the tube it causes the low pressure gas inside to form ions. The ions allow a small amount of current to flow from the electrode to the conducting layer. This is detected by an electronic circuit.

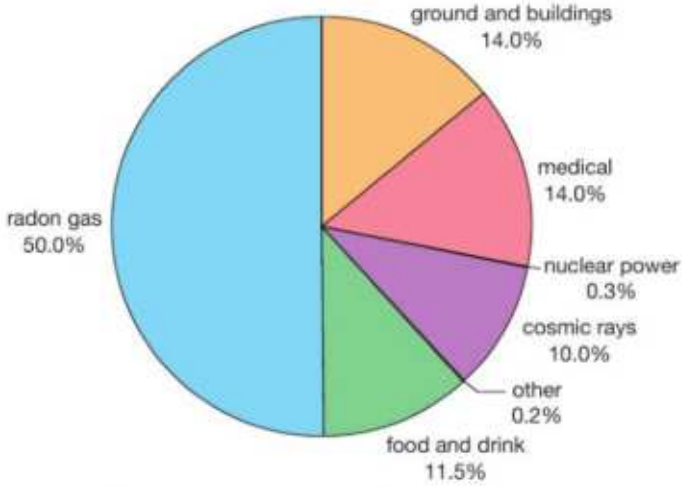


▲ Figure 18.2 A Geiger–Müller tube is used to measure the level of radiation.

The GM tube is usually linked up to a counting circuit. This keeps a count of how many ionising particles (or how much γ radiation) have entered the GM tube. Sometimes GM tubes are connected to rate meters. These measure the number of ionising events per second, and so give a measure of the radioactivity in becquerels. Rate meters usually have a loudspeaker output so the level of radioactivity is indicated by the rate of clicks produced.

BACKGROUND RADIATION

Background radiation is low-level ionising radiation that is produced all the time. This background radiation has a number of sources. Some of these are natural and some are artificial.



▲ Figure 18.3 Sources of background radiation in the UK. These are the average values – the true amounts and proportions vary from place to place.

NATURAL BACKGROUND RADIATION FROM THE EARTH

KEY POINT

When an atom of a radioactive element decays it gives out radiation and changes to an atom of another element. This may also be radioactive, and decay to form an atom of yet another element. The elements formed as a result of a radioactive element experiencing a series of decays are called decay products.

Some of the radiation we receive comes from rocks in the Earth's crust (hard outer layer). When the Earth was formed, around 4.5 billion years ago, it contained many radioactive isotopes. Some decayed very quickly but others are still producing radiation. Some of the decay products of these long-lived radioactive materials are also radioactive, so there are radioactive isotopes with much shorter half-lives (see page 673) still present in the Earth's crust.

One form of uranium is a radioactive element that decays very slowly. Two of its decay products are gases. These are the radioactive gases radon and thoron. Radon-222 is a highly radioactive gas produced by the decay of radium-226. Thoron, or radium-220, is an isotope of radium formed by the decay of a radioactive isotope of thorium (thorium-232).

As these decay products are gases, they come out of radioactive rocks. They are dense gases so they build up in the basements of buildings. Some parts of the Earth's crust have higher amounts of radioactive material so the amount of background radiation produced in this way varies from place to place. In Cornwall in the UK, for example, where the granite rock contains traces of uranium, the risk of exposure to radiation from radon gas is greater than in some other parts of the UK.

NATURAL BACKGROUND RADIATION FROM SPACE

Violent nuclear reactions in stars and exploding stars called supernovae produce cosmic rays (very energetic particles) that continuously hit the Earth. Lower energy cosmic rays are given out by the Sun. Our atmosphere gives us fairly good protection from cosmic rays but some still reach the Earth's surface.

RADIATION IN LIVING THINGS

The atoms that make up our bodies were formed in the violent reactions that take place in stars that exploded (supernovae) billions of years ago. Some of these atoms are radioactive so we carry our own personal source of radiation around with us. Also, as we breathe we take in tiny amounts of the radioactive isotope of carbon, carbon-14. Because carbon-14 behaves chemically just like the stable isotope, carbon-12, we continuously renew the amount of the radioactive carbon in our bodies (see page 681).

Carbon-14 and other radioactive isotopes are eaten by humans (and animals which are in turn eaten by humans) because they are present in all living things.

ARTIFICIAL RADIATION

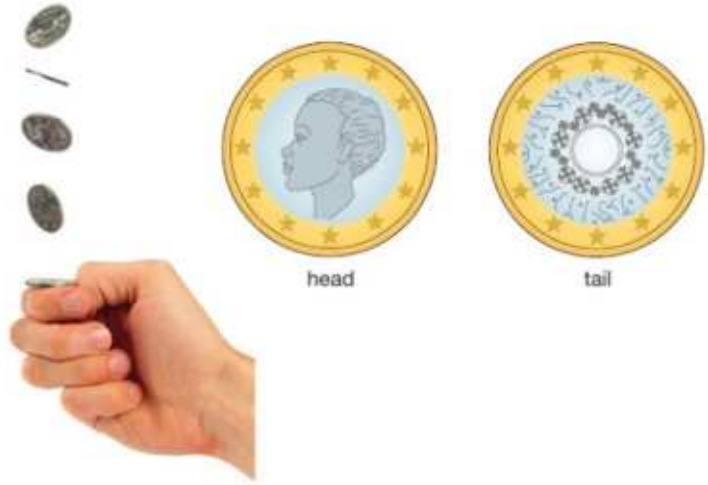
We use radioactive materials for many purposes. Generating electricity in nuclear power stations has been responsible for the leaking of radioactive material into the environment. The levels are usually small, but there have been a number of major incidents around the world, especially at Three Mile Island in the USA in 1979 and at Chernobyl in the Ukraine in 1986. The tsunami and earthquake that caused major damage and loss of life in Japan in 2011 also damaged the Fukoshima nuclear power station resulting in the release of radioactive materials into the air and the ocean as well as making a large area of land around the damaged power station unsafe for humans to live there.

Testing nuclear weapons in the atmosphere has also increased the amounts of radioactive isotopes on the Earth.

Radioactive **tracers** are used in industry and medicine. Radioactive materials are also used to treat certain forms of cancer. However, the majority of background radiation is natural – the amount produced from medical use in industry is very small indeed.

RADIOACTIVE DECAY

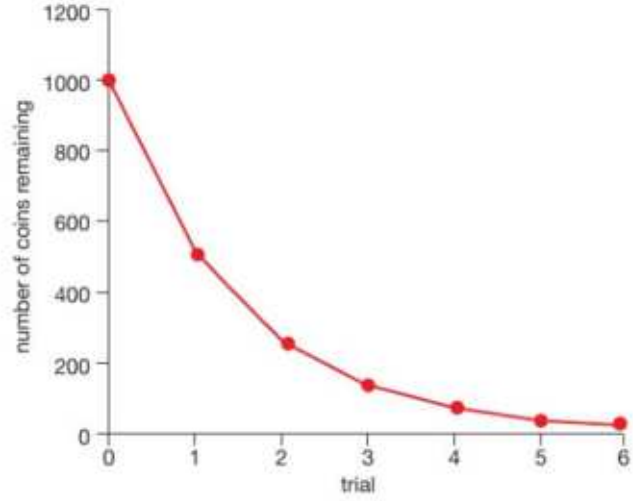
Radioactive decay is a random (unpredictable) process, just like throwing a coin. If we throw a coin we cannot say with certainty whether it will come down heads or tails. If we throw a thousand coins we cannot predict which will land heads and which will land tails. The same is true for radioactive nuclei. It is impossible to tell which nuclei will disintegrate (break down) at any particular time. However, if we threw a thousand coins we would be surprised if the number that landed as heads was not around 500. We know that a normal coin has an equal chance of landing as a head or a tail, so if we got 600 heads we would think it was unusual. If the proportion of heads were much greater than this we would be right to think that the coin was not fair.



▲ Figure 18.4 Throwing a coin

EXPERIMENTAL DEMONSTRATION OF NUCLEAR DECAY

We could, if we had the time, take 1000 coins and throw them. We could then remove all the coins that came down heads, note the number of coins remaining and then repeat the process. If we did this for, say, six trials we would begin to see the trend. A set of typical results is shown in the following table and in Figure 18.5.



▲ Figure 18.5 Coin-throwing experiment. Each time the coins are thrown about 50% of them land as 'heads' and are removed from the pile. The graph decreases steeply at first but then does so more and more slowly.

Trial	Number of coins remaining
0	1000
1	519
2	264
3	140
4	72
5	33
6	19

EXTENSION WORK

The coin-throwing experiment is a model of radioactive decay. A good model will show the features of the real process. We must remember that models have limitations, however, and do not perfectly represent the actual process. One limitation of the experiment is that of scale. In just 1 g of uranium-235 there are millions of nuclei, and our model uses just 1000 coins. The model would be better if we used, say, 1 000 000 coins, but would take too long to perform. If we use a computer model to throw the coins we could deal with more realistic numbers.

Notice that the graph in Figure 18.5 falls steeply at first and more slowly after each throw. How quickly the graph falls depends on how many heads occur on each throw. But as the number of coins decreases, the number of coins that come up heads also gets smaller. This graph follows a rule: the smaller the quantity, the more slowly the quantity decreases. The quantity here is the number of coins still in the experiment. The name for this kind of decrease proportional to size is called exponential decay.

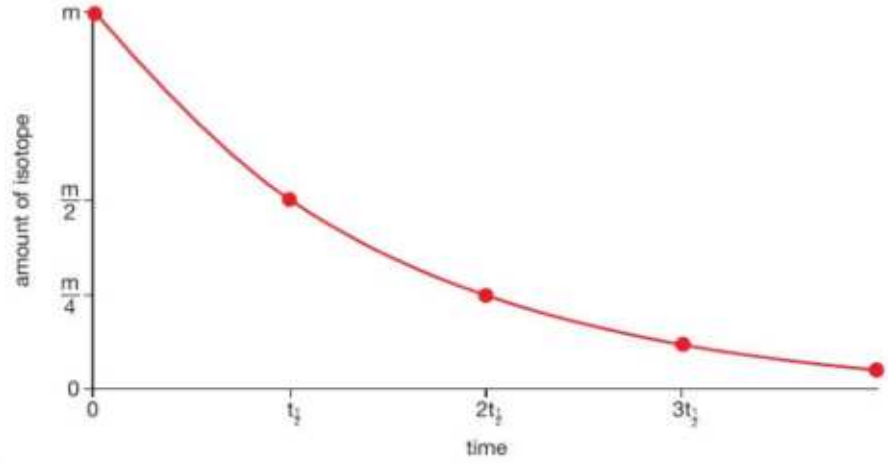
If we have a sample of a radioactive material, it will contain millions of atoms. The process of decay is random, so we don't know when an atom will decay but there will be a probability that a certain fraction of them will disintegrate in a particular time. This is the same as in the coin toss – there was a 50% probability that the coins would land heads each time we conducted a trial. Once an unstable nucleus has disintegrated, it is out of the game – it won't be around to disintegrate during the next period of time. If we plot a graph of number of disintegrations per second against time for a radioactive isotope we would, therefore, expect the rate of decay to fall as time passes because there are fewer nuclei to decay.

HALF-LIFE

Our coin-tossing model of radioactive decay shows a graph that approaches the horizontal axis more and more slowly as time passes. The model will produce a number of throws after which all the coins have been taken out of the game. The number is likely to vary from trial to trial because the model becomes less and less reliable as the number of coins becomes smaller. With real radioactive decay we use a measure of activity called the **half-life**. This is defined as follows.

The half-life of a radioactive sample is the average time taken for half the original mass of the sample to decay. If the amount of radioactive matter has halved then the activity of the decay halves – this activity is what is measured in finding the half-life of an isotope. The half-life is different for different radioactive isotopes.

Figure 18.6 shows what this means. After one half-life period, $t_{\frac{1}{2}}$, the amount of the original unstable element has halved. After a second period of time, $t_{\frac{1}{2}}$, the amount has halved again, and so on.



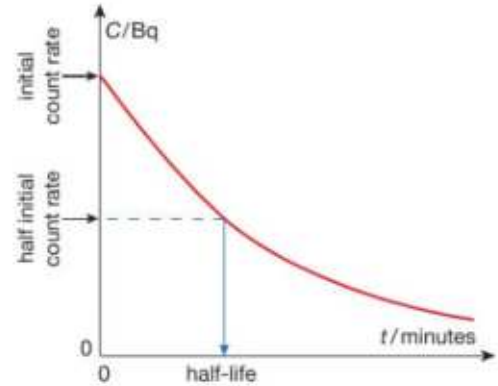
▲ Figure 18.6 Graph showing the half-life period for a radioactive isotope

MEASURING THE HALF-LIFE OF A RADIOACTIVE ISOTOPE

To measure the half-life of a radioactive material (**radioisotope**) we must measure the activity of the sample at regular times. This is done using a Geiger–Müller (GM) tube linked to a rate meter. Before taking measurements from the sample, we must measure the local background radiation. We must **subtract** the background radiation measurement from measurements taken from the sample so we know the radiation produced by the sample itself. We then measure the rate of decay of the sample at regular time intervals. The rate of decay is shown by the count rate on the rate meter. The results should be recorded in a table like the one shown below.

Average background radiation measured over 5 min = x Bq		
Time, t / min	Count rate / Bq	Corrected count rate, C / Bq
0	y_0	$y_0 - x$
5	y_5	$y_5 - x$

The rate of decay, C, corrected for background radiation, is proportional to the amount of radioactive isotope present. If we plot a graph of C against time, t, we can measure the half-life from the graph, as shown in Figure 18.7.



▲ Figure 18.7 You can find the half-life by reading from the graph the time taken for the count rate to halve.

As we have already mentioned, different isotopes can have very different half-lives. Some examples of different half-lives are shown in the table below.

Isotope	Half-life	Decay process
uranium-238	4.5 billion years	α particle emission
radium-226	1590 years	α particle emission, γ ray emission
radon-222	3.825 days	α particle emission

Isotopes with short half-lives are suited to medical use (see page 677). This is because the activity of a source will rapidly become very small as the isotope decays quickly.

Isotopes used for dating samples of organic material need to have very long half-lives. This is because the activity will become difficult to measure accurately if it drops below a certain level. In Chapter 19, we shall see that there are suitable isotopes for these different applications.

HALF-LIFE CALCULATIONS

Graphs of activity, in becquerels, against time can be used to find the half-life of an isotope, and this half-life information can be used to make predictions of the activity of the radioisotope at a later time.

EXAMPLE 1

The activity of a sample of a certain isotope is found to be 200 Bq.

If the isotope has a half-life of 20 minutes, what will the activity of the sample be after one hour?

After 20 minutes the activity will have halved to 100 Bq.

After 40 minutes (two half-lives) it will have halved again to 50 Bq. After 60 minutes it will have halved again, so the activity will be 25 Bq.

What is the level of activity of this sample after three hours?

Three hours = 9 × 20 minutes – that is, nine half-life periods. This means the activity will have halved nine times. The level of activity (and the amount of the radioisotope remaining) will be:

$$\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}$$

or $\frac{1}{2^9}$ of the original value, and so $\frac{1}{512}$ of the original activity or amount.

CHAPTER QUESTIONS

More questions on radioactive decay can be found at the end of Unit 7 on page 691.

SKILLS CRITICAL THINKING

1 a Explain what is meant by background radiation.

b Explain the difference between natural background radiation and artificial background radiation.

c Give three different sources of background radiation. Say whether your examples are natural or artificial sources.

SKILLS CRITICAL THINKING

2 a Explain simply the principle of the Geiger–Müller tube.

b The Geiger–Müller tube is often connected to a rate meter. Explain what this instrument measures.

c The rate meter is calibrated in kBq. How is this unit defined?

3 a Define what is meant by the half-life of a radioactive material.

b Radioactive decay is a random process. Explain what this means.

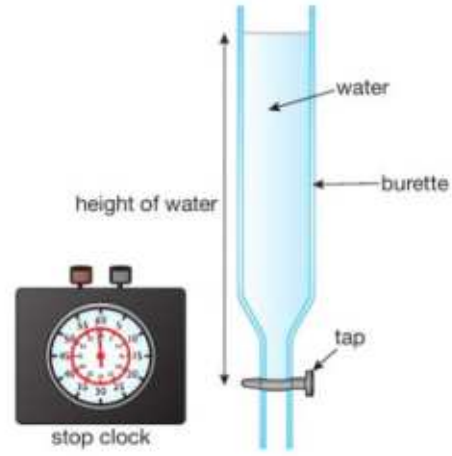
SKILLS PROBLEM SOLVING

4 The activity of a radioactive sample is measured. The activity, corrected for background radiation, is found to be 240 Bq. The activity is measured again after 1 hour 30 minutes and is now 30 Bq. What is the half-life of the sample?

5 In another model of radioactive decay, a student fills a burette with water, as shown in the diagram, and starts a timer at the instant the tap at the bottom is opened. She notes the height of the column of water at regular intervals. It takes 35 seconds to empty from 50 ml to 25 ml. Assuming that the arrangement provides a good model of radioactive decay:

a How long will it take for three quarters of the water in the burette to drain away?

b How much water should remain in the burette after 1¾ minutes?



SKILLS EXECUTIVE FUNCTION

6 A student wants to measure the half-life of a radioactive isotope. He is told the isotope has a half-life of between 10 and 20 minutes. Illustrating your answers as appropriate, describe:

a the measurements that he should take

b how he should use the measurements to arrive at an estimate of the half-life for the isotope.

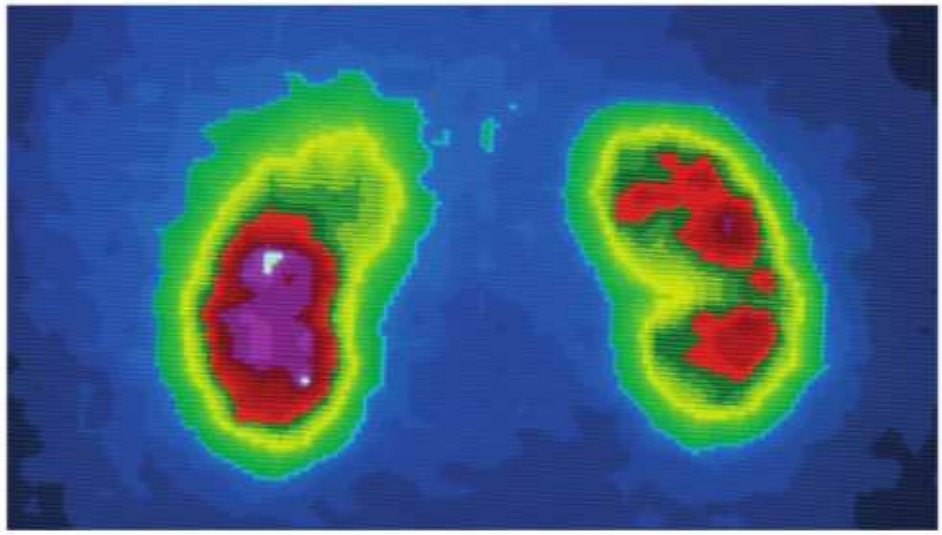
19 APPLICATIONS OF RADIOACTIVITY

Radioactivity has a wide variety of uses, including medicine, industry and power generation. In this chapter, you will read about these uses and also learn about the dangers associated with the use of radioactivity.

LEARNING OBJECTIVES

- Describe uses of radioactivity in industry and medicine
- Describe the difference between contamination and irradiation
- Be able to describe the dangers of ionising radiations including:
  - that radiation can cause mutations in living organisms
  - that radiation can damage cells and tissue
  - the problems arising from the disposal of radioactive waste and how the associated risks can be reduced

THE USE OF RADIOACTIVITY IN MEDICINE



▲ Figure 19.1 This scan shows the kidneys in a patient's body.

USING TRACERS IN DIAGNOSIS

Radioactive isotopes are used as tracers to help doctors identify diseased organs (like the kidneys or the liver). A radioactive tracer is a chemical compound that emits gamma radiation. The tracer is taken orally (swallowed) by the patient or injected. Its journey around the body can then be traced (followed) using a gamma ray camera.

Different compounds are chosen for different diagnostic tasks. For example, the isotope iodine-123 is absorbed by the thyroid gland (a part of the body found in the neck that controls growth) in the same way as the stable form of iodine. The isotope decays and emits gamma radiation. A gamma ray camera can then be used to form a clear image of the thyroid gland.

The half-life of iodine-123 is about 13 hours. A short half-life is important as this means that the activity of the tracer decreases to a very low level in a few days.

EXTENSION WORK

The isotope used in medicine is what is called a metastable form of technetium-99 called technetium-99m.

Other isotopes are used to image specific parts of the body. Technetium-99 is the most widely used isotope in medical imaging. It is used to help identify medical problems that affect many parts of the body. Figure 19.1 shows a scan of a patient's kidneys. It shows clearly that one of the kidneys is not working properly.



▲ Figure 19.2 Scanner used to provide 3D images of a patient's body

Imaging techniques enable doctors to produce three-dimensional (3D) computer images of parts of a patient's body. These are of great value in diagnosis. Figure 19.2 shows the kind of equipment used for three-dimensional imaging.

TREATMENT

Radiation from isotopes can have various effects on the cells that make up our bodies. Low doses of radiation may have no lasting effect. Higher doses may cause the cells to stop working properly as the radiation damages the DNA in the cells. This can lead to abnormal growth and cancer. Very high doses will kill living cells.

Cancer can be treated by surgery that involves cutting out cancerous cells. Another way of treating cancer is to kill the cancer cells inside the body. This can be done with chemicals containing radioactive isotopes. Unfortunately, the radiation kills healthy cells as well as diseased ones. To reduce the damage to healthy tissue, chemicals are used to target the location of the cancer in the body. They may emit either alpha or beta radiation. Both these types of radiation have a short range in the body, so they will affect only a small volume of tissue close to the target.

The radioisotope iodine-131 is used in the treatment of various diseases of the thyroid gland. It has a half-life of about eight days and decays by beta particle emission.

STERILISATION USING RADIATION

Gamma radiation can kill **bacteria** and viruses. It is therefore used to kill these microorganisms on surgical instruments and other medical equipment. The technique is called irradiation. The items to be **sterilised** are placed in secure bags to ensure that they cannot be re-contaminated before use. The gamma radiation will pass through the packaging and destroy bacteria without damaging the item.

KEY POINT

Irradiation will not destroy any poisons that bacteria may have already produced in the food before it is treated.
Irradiation does not destroy vitamins in the food like other means of killing bacteria, such as high-temperature treatment.

Some food products are treated in a similar way to make sure that they are free from any bacteria that will cause the food to rot or will cause food poisoning. The irradiation of food is an issue that causes concern among the public and is not a widely used procedure at the present time.

Irradiation such as the deliberate exposure of food products and surgical instruments to controlled amounts of radiation should not be confused with radioactive contamination. If radioactive waste is accidentally released either into the air or the sea it could result in fish, animals or agricultural crops being contaminated with radioactive material.



▲ Figure 19.3 Gamma radiation is used to sterilise medical equipment.

THE USE OF RADIOACTIVITY IN INDUSTRY

GAMMA RADIOGRAPHY

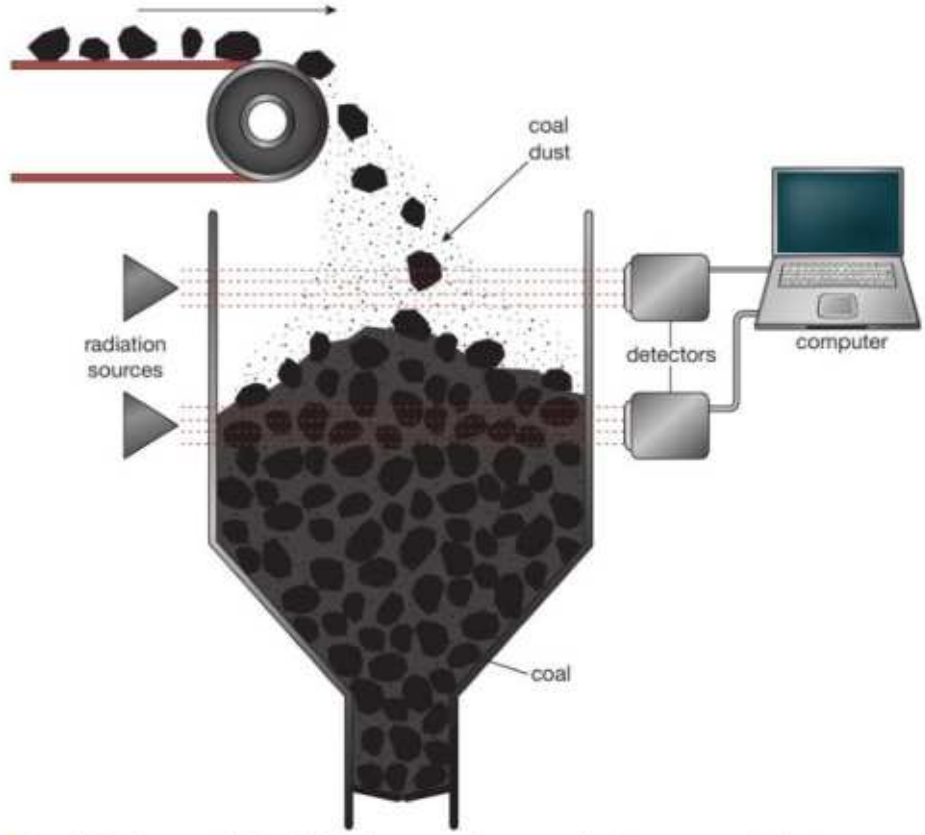
A gamma ray camera is like the x-ray cameras used to examine the contents of your luggage at airports. A source of gamma radiation is placed on one side of the object to be **scanned** and a gamma camera is placed on the other. Gamma rays pass through more objects than x-rays. They can be used to check for faults in casting (making things out of metal) or welding (joining metal objects together). Without the technique of gamma radiography, neither problem could be detected unless the welding or casting were cut through. An additional advantage of gamma radiography over the use of x-rays for this purpose is that gamma sources can be small and do not require a power source or large equipment.

GAUGING

In industrial processes, raw materials and fuel are stored in large tanks called hoppers. Figure 19.4 shows how radioactive isotopes are used to gauge, or measure, how much material there is in a storage container.

The coal absorbs a large amount of the radiation so the reading on the lower detector will be small. As the upper part of the hopper is empty the upper detector will have a high reading.

This method of gauging has several advantages over other methods. There is no contact with the material being gauged. Also, coal dust might cause false readings with an optical gauging system (one using light beams). Coal dust is much less dense than coal so the gamma ray system still works properly.

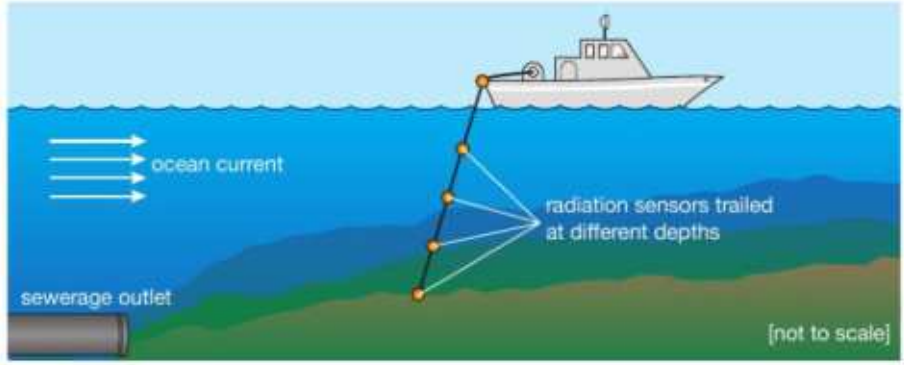


▲ Figure 19.4 The amount of coal in the hopper can be measured using gamma radiation.

Another example of gauging uses a similar process to monitor the thickness of plastic sheeting and film. The thicker the sheet, the greater the amount of radiation it absorbs and the amount passing through gets smaller. By measuring the amount of radiation that passes through the sheeting, its thickness can be closely controlled during manufacture.

TRACING AND MEASURING THE FLOW OF LIQUIDS AND GASES

Radioisotopes are used to check the flow of liquids in industrial processes. Very tiny amounts of radiation can easily be detected. Complex piping systems, like those used in in power stations, can be monitored for leaks. Radioactive tracers are even used to measure the rate of spread of sewage (human waste) (Figure 19.5)!



▲ Figure 19.5 Radioactive tracers released with the sewage allow its spread to be monitored to make sure the concentration does not reach harmful levels in any area.

RADIOACTIVE DATING

A variety of different methods involving radioisotopes are used to date minerals and organic matter. The most widely known method is radiocarbon dating. This is used to find the age of organic matter – for example, from trees and animals – that was once living. We shall also look at techniques that are used to find the age of inorganic material like rocks and minerals.

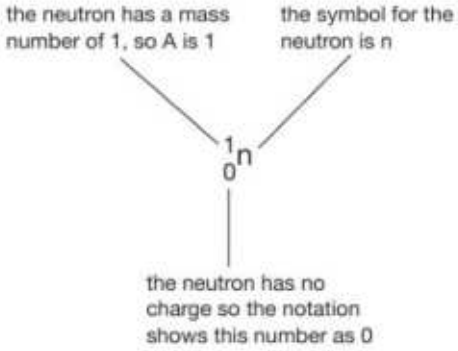
RADIOCARBON DATING

Radiocarbon dating measures the level of an isotope called carbon-14 (C-14). This is made in the atmosphere. Cosmic rays from space are continually raining down upon the Earth. These have a lot of energy. When they hit atoms of gas in the upper layers of the atmosphere, the nuclei of the atoms break apart. The parts fly off at high speed. If they hit other atoms they can cause nuclear transformations (changes) to take place. These transformations turn the elements in the air into different isotopes. One such collision involves a fast-moving neutron striking an atom of nitrogen. (Nitrogen forms nearly 80% of our atmosphere.) The nuclear equation for this process is:

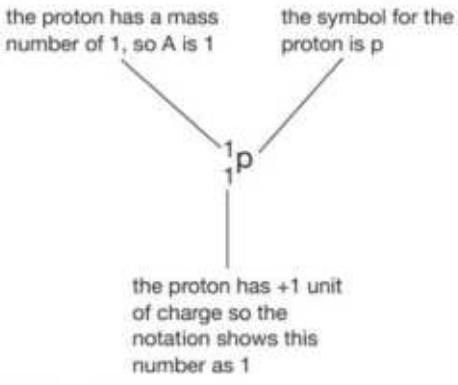
$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}p$$

Notice that, as in the other nuclear equations we have seen, the top numbers – which show the number of nucleons – add up to the same total on each side of the equation. This is because the mass number is conserved. The bottom numbers – which show the amount of charge on the particles – are also conserved.

You have seen the notation for neutrons and protons in Chapter 17. A reminder of neutron notation is shown in Figure 19.6, and of proton notation in Figure 19.7.



▲ Figure 19.6 The neutron



▲ Figure 19.7 The proton

The result of the collision of a neutron with a nitrogen atom is a nuclear transformation. The nitrogen atom is transformed into an atom of the radioactive isotope of carbon, carbon-14.

As we have already mentioned, isotopes of an element have the same chemical behaviour. This means that the carbon-14 atoms react with oxygen in our atmosphere to form carbon dioxide, just like the much more common and stable isotope, carbon-12. The carbon dioxide is then absorbed by plants in the process of **photosynthesis**. As a result, a proportion of the carbon that makes up any plant will be the radioactive form, carbon-14. Included in plant material, the radioactive isotope carbon-14 enters the food chain, which means that animals and humans will also have a proportion of carbon-14 in their bodies. These carbon-14 atoms will decay but, in living plants and animals, they are continuously replaced by new ones.

When an organism (living thing) dies, the replacement process stops. As time passes, the radioactive carbon decays and the proportion of radioactive carbon in the remains of the plant or animal, compared with the stable carbon isotope, decreases.

The half-life for the decay of carbon-14 is approximately 5600 years. This means that every 5600 years the proportion of carbon-14 in dead plant and animal material will halve. The amount of carbon-14 present in a sample of dead plant or animal material is found by measuring the activity of the sample. This is compared with the amount of carbon-14 that would have been present when the sample was part of a living organism. From this, it is possible to estimate when the source of the sample died.

EXAMPLE 1

120 g of living wood has a radioactive activity (corrected for background radiation) of 24 Bq. A 120 g sample of wood from an historical site is found to have an activity of 6 Bq. If the half-life of carbon-14 is 5600 years, estimate the age of the wood from the site.

$$6 \text{ Bq} = 24 \text{ Bq} \times \frac{1}{2} \times \frac{1}{2}$$

Since the activity of the sample has halved twice from that expected in living wood, two half-lives must have passed.

The age of the sample is therefore around 2 × 5600 years = 11 200 years.

There are limitations to the method of radiocarbon dating. It assumes the level of cosmic radiation reaching the Earth is constant, which is not necessarily accurate. Fortunately, the technique has been adjusted to take the variations of cosmic ray activity into account. This is done by testing samples of a known age, like material from the mummies (preserved corpses) of Egyptian Pharaohs and from very ancient living trees.

The radiocarbon method is not used to date samples older than 50 000–60 000 years because, after 10 half-lives, the amount of carbon-14 remaining in samples is too small to measure accurately.

EXTENSION WORK

Radiocarbon dating may be used as a context in questions about the half-life of radioactive isotopes. What follows on dating the age of rocks is included for interest only.

DATING THE AGE OF ROCKS

Inorganic, non-living matter does not absorb carbon-14, so different techniques must be used for finding out the age of rocks and minerals.

When a radioactive substance decays it transforms into a different isotope, sometimes of the same element, sometimes of a different element. The original radioisotope is called the parent nuclide (unstable nucleus) and the product is called the daughter nuclide. Many of the products of decay, the daughter isotopes, are also unstable and these too decay in turn. This means that as the parent isotope decays it breeds a whole family of elements in what is called a decay series. The end of the decay series is a stable isotope – one that does not decay further.

The table shows some radioactive parent isotopes with the stable daughters formed at the end of their particular decay series. The half-life quoted is the time for half the original number of parent nuclei to decay to the stable daughter element.

Radioactive parent isotope	Stable daughter element	Half-life / years
potassium-40	argon-40	1.25 billion
thorium-232	lead-208	14 billion
uranium-235	lead-207	704 billion
uranium-238	lead-206	4.47 billion
carbon-14	nitrogen-14	5568

For rocks containing such radioactive isotopes, the proportion of parent to stable daughter nuclide gives a measure of the age of the rock. Notice that the half-lives of most of the radioactive parent isotopes are extremely long, in some cases greater than the lifetime of the Earth.

The decay series of potassium-40 ends with argon gas. As potassium-40 decays in igneous rock, the argon produced remains trapped in the rock. Igneous rocks are formed when molten rock becomes solid. Igneous rocks are **non-porous**. The proportion of argon to potassium-40 again gives a measure of the age of the rock.

THE DANGERS TO HEALTH OF IONISING RADIATION

Ionising radiation can damage the molecules that make up the cells of living tissue. Cells suffer this kind of damage all the time for many different reasons. Fortunately, cells can repair or replace themselves given time so, usually, no permanent damage results. However, if cells suffer repeated damage because of ionising radiation, the cell may be killed. Alternatively the cell may start to behave in an unexpected way because it has been damaged. We call this effect cell mutation. Some types of cancer happen because damaged cells start to divide uncontrollably and no longer perform their correct function.

Different types of ionising radiation present different risks. Alpha particles have the greatest ionising effect, but they cannot pass through many materials. This means that an alpha source presents little risk, as alpha particles do not penetrate (pass through) the skin. The problem of alpha radiation is much greater if the source of alpha particles is taken into the body. Here the radiation will be very close to many different types of cells and they may be damaged if the exposure is prolonged. Alpha emitters can be breathed in or taken in through eating food. Radon gas is a decay product of radium and is an alpha emitter. It therefore presents a real risk to health. Smokers greatly increase their exposure to this kind of damage as they draw the radiation source right into their lungs (cigarette smoke contains radon).

Beta and gamma radiation do provide a serious health risk when outside the body. Both can penetrate skin and flesh (body) and can cause cell damage by ionisation. Gamma radiation, as we have mentioned earlier, is the most penetrating. The damage caused by gamma rays will depend on how much of their energy is absorbed by ionising atoms along their path. Beta and gamma emitters that are absorbed by the body present less risk than alpha emitters, because of their lower ionising power.

In all cases, the longer the period of exposure to radiation the greater the risk of serious cell damage. Workers in the nuclear industry wear badges to indicate their level of exposure. Some are pieces of photographic film that become increasingly 'foggy' (unclear) as the radiation exposure increases. Another type of badge uses a property called thermoluminescence. Thermoluminescence means that the exposed material will give out light when it is warmed. The radiation releases energy to make heat so the thermoluminescent badges give out more light when exposed to higher levels of radiation. Workers have their badges checked regularly and this gives a measure of their overall exposure to radiation.

SAFE HANDLING OF RADIOACTIVE MATERIALS

Samples of radioactive isotopes used in schools and colleges are very small. This is to limit the risk to users, particularly those who use them regularly – the teachers! Although the risk is small, certain precautions must be followed. The samples are stored in lead-lined containers to block even the most penetrating form of radiation, gamma rays. The containers are clearly labelled as a radiation hazard (danger) and must be stored in a locked metal cabinet. The samples are handled using tongs and are kept as far from the body as possible.

In the nuclear industry and research laboratories, much larger amounts of radioactive material are used. These have to be handled with great care. Very energetic sources will be handled remotely by operators who are protected by lead shields, concrete and thick glass viewing panels. As has been mentioned earlier, neutron radiation is absorbed by lighter elements and waste materials, like spent uranium fuel rods from nuclear reactors, are stored under water until the neutron radiation levels drop to a safe level.



▲ Figure 19.8 Radioactive samples are stored in lead-lined containers and are handled with tongs or protected fingers.



▲ Figure 19.9 Industrial sources of radioactivity must be handed with a lot of care.

The major problem with nuclear materials is long-term storage. Some materials have extremely long half-lives so they remain active for thousands and sometimes tens of thousands of years. Nuclear waste must be stored in sealed containers that must be capable of containing the radioactivity for enormously long periods of time.

CHAPTER QUESTIONS

More questions on applications of radioactivity can be found at the end of Unit 7 on page 691.

SKILLS REASONING

1 The most widely used isotope in medicine is technetium-99m. It has a half-life of six hours and decays by the emission of low-energy gamma rays and beta particles.

a Explain why the characteristics of technetium-99m make it suitable for diagnostic use in medicine.

SKILLS CREATIVITY, REASONING

b Technetium-99m can be chemically attached to a wide variety of pharmaceutical products so that it can be targeted at particular tissues or organs. How can its progress through the body be measured and monitored?

SKILLS REASONING

2 Technetium-99m is produced from molybdenum-99 in a device called a technetium generator. Which decay process – α, β or γ – could cause molybdenum-99 to decay to technetium-99m? Explain your answer.

HINT

Look at Chapter 17.

SKILLS CREATIVITY, REASONING

3 A radioactive isotope of iodine is used in both the diagnosis and treatment of a condition of the thyroid gland. This gland naturally takes up ordinary iodine as part of its function. If a patient has an overactive thyroid it concentrates too much iodine in the gland and this has serious effects on the patient's health.

How might the radioisotope iodine-131 be used to:

a identify an overactive thyroid gland?

b treat the overactive thyroid?

(Iodine-131 has a half-life of eight days and is a high-energy beta emitter.)

SKILLS CRITICAL THINKING

4 a Explain the difference between radioactive contamination and irradiation.

b Give an example of a use of irradiation.

SKILLS CREATIVITY, REASONING

5 Paper is made in a variety of different 'weights', with different thicknesses. How could ionising radiation be used to check the thickness of paper during production? You should consider the following:

- the type of radiation to be used
- how it will be used to measure the paper thickness
- what checks should be made to ensure that the measurements are accurate
- safety procedures.

SKILLS CRITICAL THINKING

6 Radiocarbon dating is used to estimate the age of organic (once-living) materials. It uses a radioisotope of carbon, carbon-14 (C-14).

a How is carbon-14 formed?

b Why does all living matter contain a proportion of C-14?

c What happens to the proportion of C-14 in an organism once it has died?

d What assumptions are made in the process of radiocarbon dating?

e Why is this method unsuitable for accurately dating material that is more than 50 000 years old?

SKILLS PROBLEM SOLVING

7 Most radioactive isotopes of elements have half-lives that are extremely short compared to the age of the Earth. The Earth is about 4.5 billion years old. Radium has a half-life of only about 1600 years.

a How many half-lives of radium have there been since the Earth formed?

SKILLS ANALYSIS

Student A says all the radium formed when the Earth condensed out of the Sun's atmosphere, should have decayed away to an unmeasurably small amount by now.

Student B says that it depends on how much there was to start with.

Student C says that there is still a significant amount of radium on the Earth.

b Which student or students are correct? Give reasons for your answer.

SKILLS REASONING

8 An isotope that decays by alpha emission is relatively safe when outside the body but very dangerous if absorbed by the body, either through breathing or eating.

a Explain why this is so.

b Why is radon-220 a particularly dangerous isotope?

20 FISSION AND FUSION

Scientists have speculated about the nature of the atom for thousands of years, but it is only relatively recently that our current ideas were developed. In this chapter you will read about how our ideas about the structure of the atom have developed over the centuries and how we use nuclear energy to produce electricity.

LEARNING OBJECTIVES

- Know that nuclear reactions, including fission, fusion and radioactive decay, can be a source of energy
- Understand how a nucleus of U-235 can be split (the process of fission) by collision with a neutron, and that this process releases energy as kinetic energy of the fission products
- Know that the fission of U-235 produces two radioactive daughter nuclei and a small number of neutrons
- Describe how a chain reaction can be set up if the neutrons produced by one fission strike other U-235 nuclei
- Describe the role played by the control rods and moderator in the fission process
- Understand the role of shielding around a nuclear reactor
- Explain the difference between nuclear fusion and nuclear fission
- Describe nuclear fusion as the creation of larger nuclei resulting in a loss of mass from smaller nuclei, accompanied by a release of energy
- Know that fusion is the energy source for stars
- Explain why nuclear fusion does not happen at low temperatures and pressures, due to electrostatic repulsion of protons

NUCLEAR REACTIONS AS A SOURCE OF ENERGY

Nuclear reactions involve a change in the qualities of atoms. Heavy atoms may split into lighter atoms and other pieces in a process called **fission**. Lighter atoms may be forced to join together to make heavier atoms in a process called fusion. In either process, the mass of the starting atoms is greater than the mass of the products. This missing mass has been converted into energy.

Within the core of the Earth, radioactive isotopes of elements like uranium, thorium and potassium provide a large proportion of the heat within the Earth itself through radioactive decay.

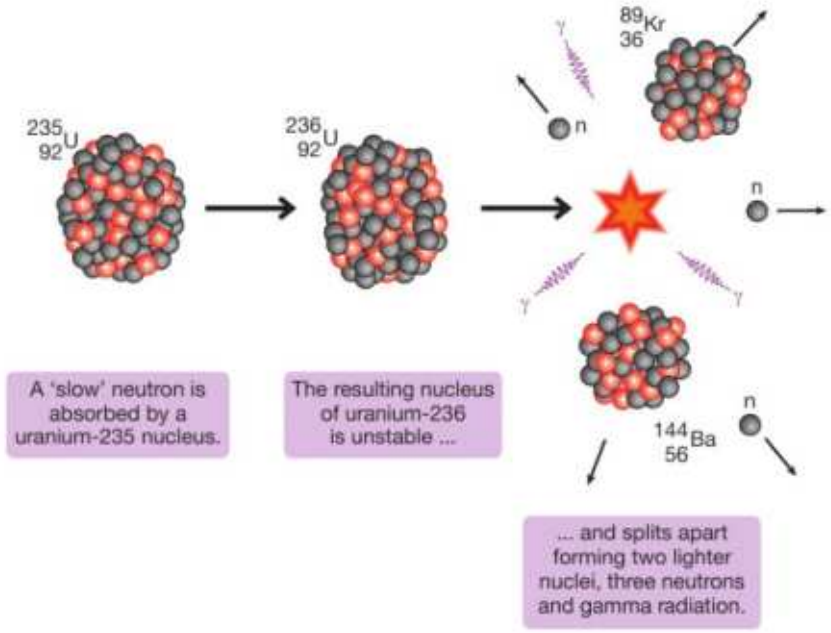
In the Sun, hydrogen is converted into helium in a **fusion reaction** providing us with a continuous supply of energy in the form of heat and other electromagnetic radiation.

NUCLEAR FISSION

Uranium-235 is used as fuel in a nuclear reactor. It is used because its nuclei can be split by a neutron. The process of splitting an atom is called fission.

Uranium-235 is called a fissile material because it goes through the splitting process easily. The fission process is shown in Figure 20.1.

In the fission reaction, a slow-moving neutron is absorbed by a nucleus of uranium-235.



▲ Figure 20.1 One example of fission of uranium-235

The resulting nucleus of uranium-236 is unstable and splits apart. The fragments of this decay are the two daughter nuclei of barium-144 and krypton-89. The decay also produces gamma radiation and three more neutrons. The equation for this decay is:

$$^{236}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,^{1}_{0}n + \gamma \text{ radiation}$$

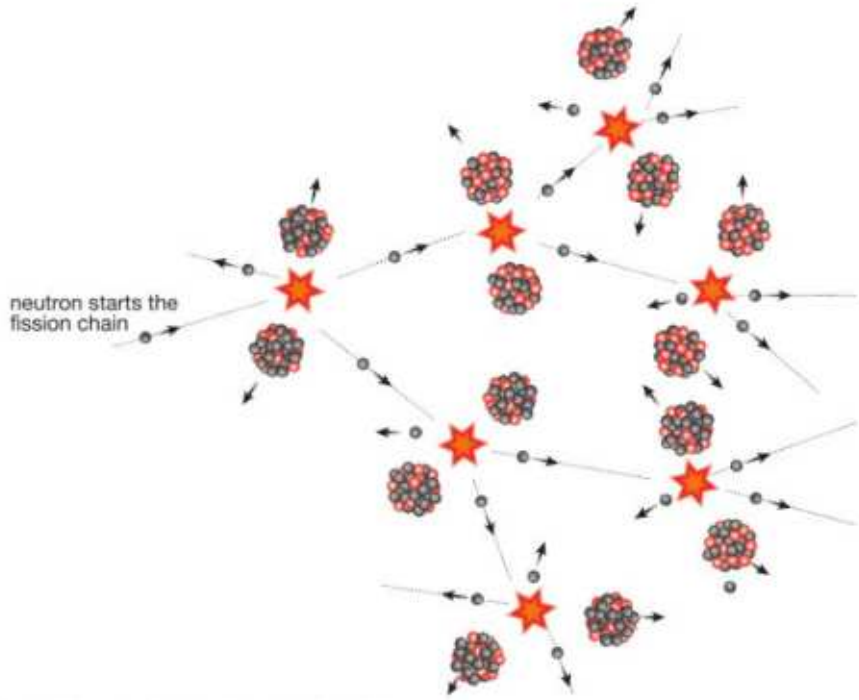
The fission reaction produces a huge amount of energy. This is because the mass of the products, the barium and krypton nuclei and the three neutrons, is slightly less than that of the original uranium-236 nuclei. This lost mass is converted to energy. Most of the energy is carried away as the kinetic energy of the two lighter nuclei. Some is emitted as gamma radiation. The three neutrons produced by the fission may hit other nuclei of uranium-235, so causing the process to repeat, as shown in Figure 20.2. If one neutron from each fission causes one nearby uranium-235 to split, then the fission reaction will keep going. If more than one neutron from each fission causes fission in surrounding nuclei, then the reaction gets faster and faster – a bit like an avalanche.

EXTENSION WORK

A 'slow' neutron is a low-energy neutron produced by a nuclear decay. Faster moving, more energetic neutrons do not cause fission.

This is called a chain reaction. Each fission results in more nuclei splitting apart. If the amount of uranium-235 is small, many of the neutrons released do not hit other uranium nuclei and the reaction does not get faster and faster. For a chain reaction to happen there must be a minimum amount of the uranium-235. This minimum amount is called the critical mass.

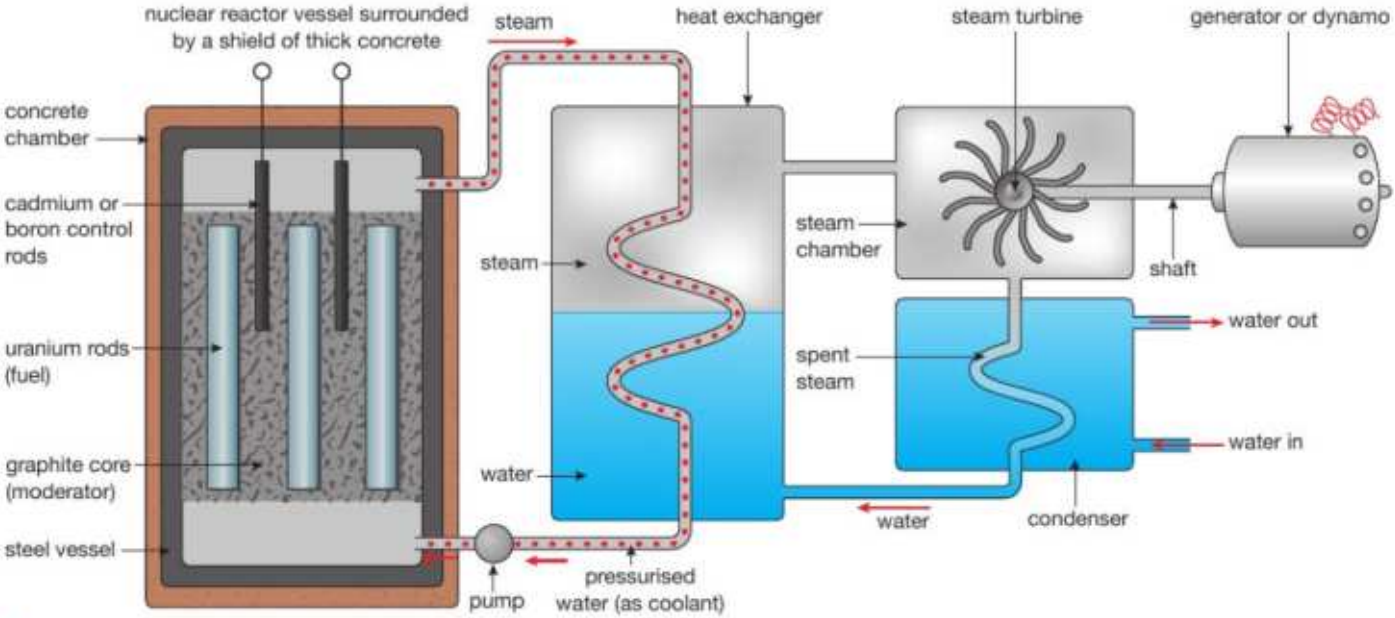
In an atomic bomb two pieces of fissile material (isotopes that can be triggered into splitting apart) that are smaller than the critical mass are forced together under high pressure to form a mass greater than the critical mass. The result is a chain reaction with the rapid and uncontrolled release of huge amounts of energy.



▲ Figure 20.2 A chain reaction in uranium-235

If this is allowed to take place in a nuclear reactor, the reactor core overheats, resulting in a nuclear explosion with the sudden release of enormous amounts of heat energy and radiation. In a nuclear reactor the process is controlled so that the heat energy is released over a longer period of time. The heat produced in the core or heart of the reactor is used to heat water. The steam produced then drives turbines (engines) to turn generators. The basic parts of a nuclear reactor are shown in Figure 20.3.

The reactor core contains fuel rods of enriched uranium. Enriched uranium is uranium-238 with a higher proportion of uranium-235 than is found in natural reserves of uranium. Graphite is used as a **moderator**. The job of



▲ Figure 20.3 A nuclear reactor controls a chain reaction so that heat energy is released slowly.

the moderator is to absorb some of the kinetic energy of the neutrons to slow them down. This is because slow neutrons are more easily absorbed by uranium-235. A neutron slowed in this way can start the fission process.

In the nuclear reactor there are also **control rods**, made of boron or cadmium. These absorb the neutrons and take them out of the fission process completely. When the control rods are fully inside the core, the chain reaction is almost completely stopped and the rate of production of heat is low. As the control rods are withdrawn, the rate of fission increases producing heat at a greater rate.

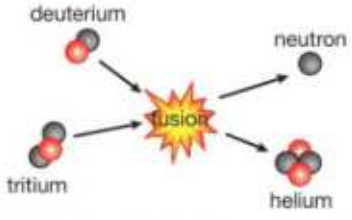
The reactor vessel is made of steel and surrounded by a concrete layer about 5 metres in thickness. This prevents any radiation escaping, even neutrons.

The nuclear process in a reactor produces a variety of different types of radioactive material. Some have relatively short half-lives and decay rapidly. These soon become safe to handle and do not present problems of long-term storage. Other materials have extremely long half-lives. These will continue to produce dangerous levels of ionising radiation for thousands of years. These waste products present a serious problem for long-term storage. They are usually sealed (closed) in containers which are then buried deep underground. The sites for underground storage have to be carefully selected. The rock must be water resistant and the geology of the site must be stable – storing waste in earthquake zones or areas of volcanic activity would not be sensible.

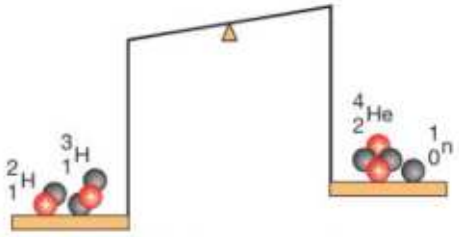
Some reactors are designed to produce plutonium. Plutonium is a very radioactive artificial element. Small amounts of plutonium represent a serious danger to health. Plutonium is another fissile material. If a large enough mass of plutonium is brought together a chain reaction will start. Plutonium can be used in the production of nuclear weapons.

Nuclear power stations do not produce carbon dioxide or acidic gases as fossil fuel power stations do. This means that nuclear power does not contribute to global warming or acid rain. Only small amounts of uranium are needed for a chain reaction and the supply of nuclear fuel will last many hundreds of years – unlike some **fossil fuels** that could run out in the next fifty years.

NUCLEAR FUSION



▲ Figure 20.4 Here a nucleus of deuterium collides with a nucleus of tritium. They undergo fusion to form the nucleus of helium, a neutron and a large amount of energy.



▲ Figure 20.5 The mass of the products of fusion is smaller than the two hydrogen nuclei.

Figure 20.4 shows a fusion process that is being used in projects to develop nuclear fusion reactors. Two isotopes of hydrogen, deuterium (H-2) and tritium (H-3), collide at very high speed. The result is the formation of a helium nucleus, a neutron and a large amount of energy. The fusion process is the energy source of our Sun and all stars.

This process uses materials that are more readily available than the uranium used in a conventional fission reactor and has the advantage of producing no radioactive waste. The problem is creating the very high temperatures needed to make the deuterium and tritium nuclei collide with enough energy to overcome the repulsive (pushing away) force between the positive electric charge in the nuclei of each isotope. The high temperature (100 million °C) liquid must be contained within a very strong magnetic field or 'magnetic bottle'. In order to increase the chance of fusion between the light nuclei in the hot liquid, the pressure within the liquid must be very high.

CHAPTER QUESTIONS

More questions on the structure of the atom can be found at the end of Unit 7 on page 691.

SKILLS CRITICAL THINKING

1 a Uranium-235 (U-235) is a fissile material. What does this mean?

b If there is a large enough mass of U-235, it may cause a chain reaction. (This is called the critical mass for the isotope.)

i Describe how a chain reaction may take place when a U-235 nucleus splits apart.

ii A chain reaction is unlikely to take place if there is only a small amount of U-235. Explain why this is so.

2 List two advantages and two disadvantages of nuclear fission as a way of producing energy.

SKILLS REASONING

3 In a nuclear fission reactor, fuel rods made up of a fissile material, like U-235, are lowered into tubes in a large block of graphite. In between the fuel rods are control rods made of boron which may be raised out of the reactor or lowered into it. The reactor container (vessel) is surrounded by steel and a very thick layer of concrete.

a Explain the purpose of the graphite around the fuel rods.

b Describe what effect the action of raising the control rods out of the reactor core has on the behaviour of the reactor.

c Explain how the workers in a nuclear power station are protected from the dangerous types of radiation produced by this nuclear reactor.

SKILLS CRITICAL THINKING

4 Describe the differences between nuclear fission and nuclear fusion.

5 Explain why creating energy in a nuclear reactor by fusion is so much more difficult than creating power by nuclear fission.

UNIT QUESTIONS

SKILLS PROBLEM SOLVING 7–8 **1**

a Which of the following particles has the smallest mass?

A alpha

B neutron

C proton

D electron

(1)

SKILLS CRITICAL THINKING 8–9

b When a radioactive isotope emits an alpha particle its

A atomic mass decreases and its atomic number decreases

B atomic mass increases and its atomic number decreases

C atomic mass decreases and its atomic number increases

D atomic mass is unchanged and its atomic number decreases

(1)

c The emission of which of the following particles from a radioisotope causes it to change into the next element in the Periodic Table?

A positron

B electron

C neutron

D alpha

(1)

SKILLS PROBLEM SOLVING 9–10

d A radioactive isotope has an activity of 1000 Bq; after 5 hours its activity has fallen to 125 Bq. The half-life of this isotope is

A 1 hour

B 75 minutes

C 125 minutes

D 2.5 hours

(1)

SKILLS CRITICAL THINKING 8–9

e Which of the following particles that may be emitted in radioactive decay is not ionising?

A alpha

B beta minus

C neutron

D beta plus

(1)

(Total 5 marks)

SKILLS PROBLEM SOLVING

2 In the Sun and other stars the temperature and pressure make hydrogen nuclei fuse together to form heavier nuclei. This process produces a very large amount of energy, various types of radiation and helium. The steps of this fusion process are shown in the following nuclear equations.

Balance these equations by filling in the boxes:

a $^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{\square}_{1}H + {}^{0}_{\square}e$ **(2)**

b $^{2}_{1}H + {}^{1}_{1}H \rightarrow {}^{\square}_{\square}He$ **(2)**

c $^{\square}_{2}He + {}^{\square}_{2}He \rightarrow {}^{4}_{2}He + {}^{1}_{\square}\square + {}^{1}_{\square}\square$ **(3)**

(Total 7 marks)

3 Here are descriptions of some nuclear particles:

Particle A has 0 mass and a charge +1.

Particle B has 1 mass and a charge 0.

Particle C has 1 mass and a charge +1.

Particle D has 0 mass and a charge –1.

Particle E has 4 mass and a charge +2.

a State which particle is an alpha. **(1)**

b State which particle is a beta minus. **(1)**

c State which particle is a positron. **(1)**

d State which particle is a proton. **(1)**

e State which particle is a neutron. **(1)**

(Total 5 marks)

SKILLS CRITICAL THINKING

4 Two types of nuclear reactor are used to produce energy. Fission reactors are already in use in nuclear power plants around the world. Fusion reactors are still at the experimental stage.

a Explain what is meant by:

i nuclear fission **(4)**

ii nuclear fusion **(4)**

b In a fission reactor the process of generating energy is a chain reaction using a suitable fissile fuel like uranium-235.

i Explain what a chain reaction is, and **(4)**

ii how it be controlled or shut down completely. **(4)**

(Total 16 marks)

SKILLS CRITICAL THINKING 9th
SKILLS REASONING 8th

5 **a** Explain the conditions that are needed to cause nuclear fusion. **(3)**

b State two reasons why nuclear fusion reactors may be a better alternative to nuclear fission reactors. **(2)**

(Total 5 marks)

SKILLS CRITICAL THINKING 7th

6 **a** Explain what the letters A and Z tell us about the structure (make up) of the nucleus of any element X.

$^{A}_{Z}X$ **(2)**

SKILLS PROBLEM SOLVING 9th

b Here is a list of the type of radiation that may be emitted (given out) by an unstable nucleus:

A alpha **B** beta **C** gamma **D** neutron

i Which type affects A but not Z? **(1)**

ii Which type affects Z but not A? **(1)**

iii Which type affects both A and Z? **(1)**

iv Which type affects neither A nor Z? **(1)**

(Total 6 marks)

MOTION IN THE UNIVERSE 695 | STELLAR EVOLUTION 701

PHYSICS UNIT 8 ASTROPHYSICS

A supernova is an exploding star. The explosion occurs when the gravitational forces within a star are so great that its core collapses releasing huge amounts of energy. It is the largest explosion to take place in space. In this section we will see how important gravitational forces are in our Universe.

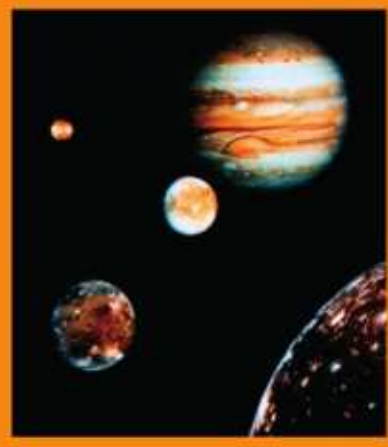


21 MOTION IN THE UNIVERSE

We live on a planet called Earth. It is one of many planets that, together with their moons, form our Solar System. Gravitational forces hold our Solar System together. These forces cause the planets, asteroids and comets to orbit the Sun, and moons and artificial satellites to orbit the planets. In this chapter we will look at the key role played by gravitational forces in controlling these movements.

UNITS

In this section you will need to use kilogram (kg) as the unit of mass, metre (m) as the unit of length, metre/second (m/s) as the unit of speed, metre/second^2 (m/s^2) as the unit of acceleration, newton (N) as the unit of force, second (s) as the unit of time and newton/kilogram (N/kg) as the unit of gravitational field strength.



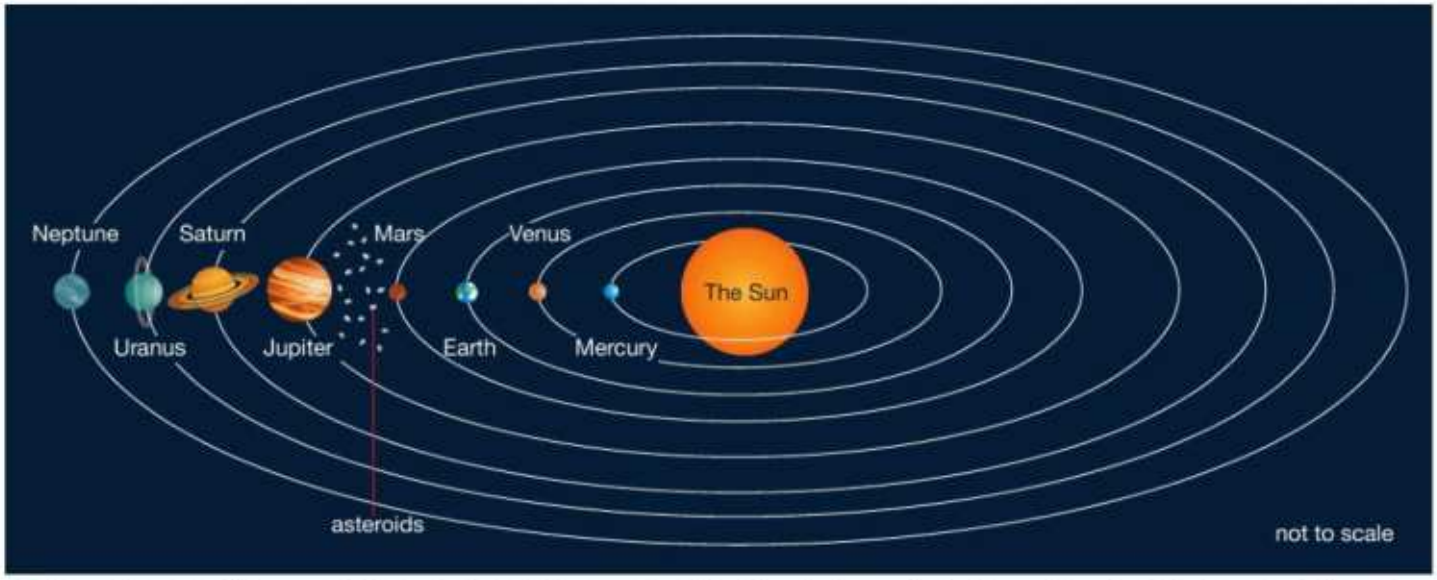
▲ Figure 21.1 The force of gravity keeps these moons in orbit around Jupiter.

LEARNING OBJECTIVES

- Explain that gravitational force causes moons to orbit planets; causes the planets and comets to orbit the Sun; causes artificial satellites to orbit the Earth
- Understand why gravitational field strength, g, varies and know that it is different on other planets and the Moon from that on the Earth
- Describe the differences in the orbits of comets, moons and planets
- Use the relationship between orbital speed, orbital radius and time period:

$$v = 2 \times \pi \times \frac{\text{orbital radius, } r}{\text{time period, } T}$$

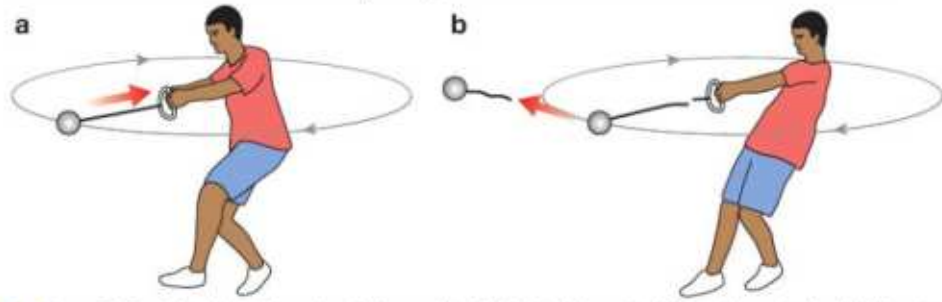
THE SOLAR SYSTEM



▲ Figure 21.2 The Earth is one of eight planets that orbit the Sun. The orbits of the planets are elliptical (an oval shape) with the Sun close to the centre.

WHY DO OBJECTS MOVE IN A CIRCLE?

Figure 21.3 shows a boy swinging a heavy ball around on a wire. To make this ball travel in a circle he needs to spin around and at the same time pull on the wire. Without this continuous pulling force the ball will not travel in a circle.



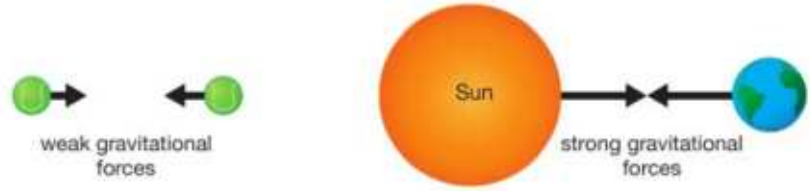
▲ Figure 21.3 **a** A 'pulling' force has to be applied to the ball to make it travel in a circle. **b** If the wire breaks or the boy releases the handle the ball flies away.

Planets and comets travel around the Sun. Moons and satellites travel around the planets. For this to happen there must be forces being applied to them. There is no string or wire to pull on as in the example above, so where do these forces come from? In 1687, Isaac Newton suggested his theory of gravity to explain these movements.

Newton suggested that between any two objects there is always a force of attraction. This attraction is due to the masses of the objects. He called this force gravitational force.

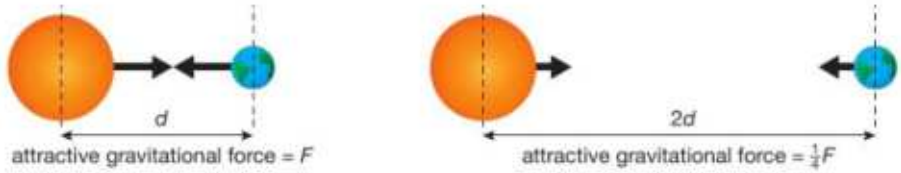
He suggested that the size of this force depends on the:

1 masses of the two objects
2 distance between the masses.



The greater the masses of the two objects the stronger the attractive forces between them.

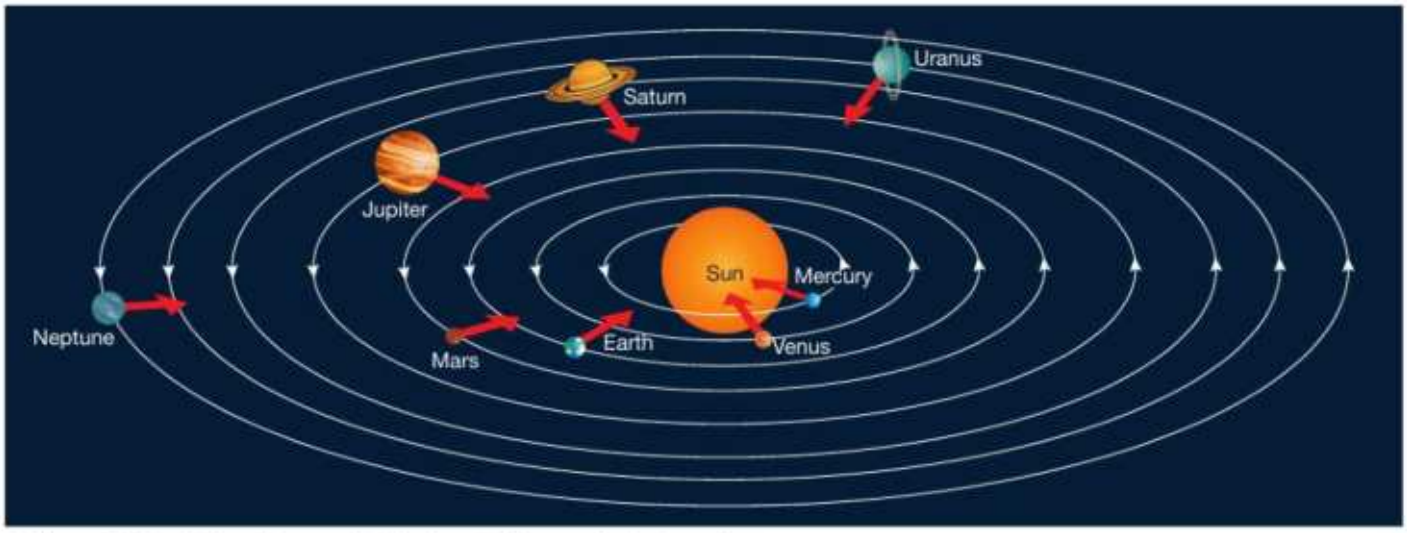
If the distance between the masses is increased the forces between them decrease.



▲ Figure 21.4 Gravitational forces obey an inverse square law – that is, if the distance between the masses is doubled, the forces between them are **quartered**; if the distance between them is **trebled**, the forces become one ninth of what they were.

The gravitational attraction between two objects with small masses is tiny. Only when one or both of the objects has a very large mass – for example, a moon or a planet – is the force of attraction obvious.

Our Sun is massive. It contains over 99% of the mass of the Solar System. It is the gravitational attraction between this mass and each of the planets that holds the Solar System together and causes the planets to follow their curved paths.



▲ Figure 21.5 Gravitational forces make the planets follow nearly circular paths.

Those planets that are closest to the Sun feel the greatest attraction and so follow the most curved paths. Planets that are the furthest from the Sun feel the weakest pull and follow the least curved path.

EXTENSION WORK

The planet Neptune is a very long way from the Sun so the gravitational force between them is very small. This means that the orbit of Neptune is not very curved and it takes a very long time for it to complete one orbit.

Planet	Average distance from Sun compared with the Earth	Time for one orbit of the Sun in Earth years
Mercury	0.4	0.2
Venus	0.7	0.6
Earth	1.0	1.0
Mars	1.5	1.9
Jupiter	5.0	12
Saturn	9.5	30
Uranus	19	84
Neptune	30	165



▲ Figure 21.6 Some of the many moons of Saturn.

SATELLITES AND MOONS

A satellite is an object that orbits a planet. There are two types of satellite: natural and artificial (human-made).

Natural satellites are called moons. The Earth has just one moon. It is the fifth largest moon in our Solar System, approximately 340 000 km from Earth, and takes just over 27 days to complete one orbit. Although we call our moon 'The Moon' it is not unique. Many planets have moons. Some have more than one, for example, Mars has two moons while Jupiter and Saturn have more than 60 each. All moons have circular orbits because of the gravitational forces between them and their planet.

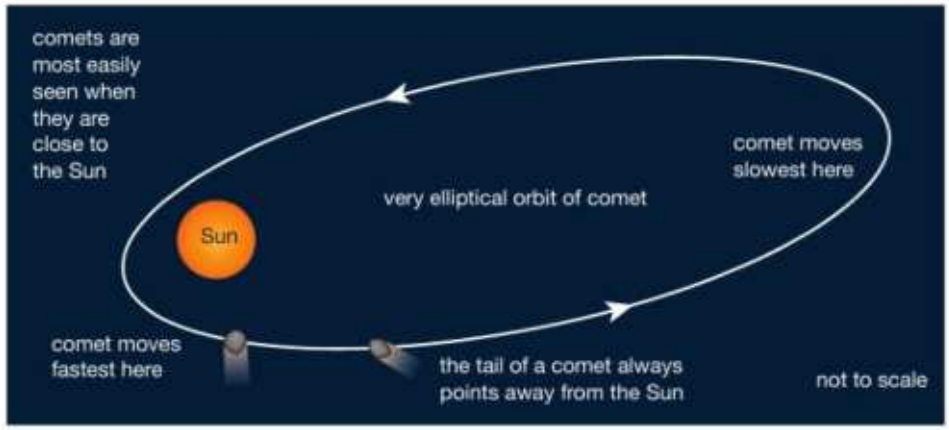


▲ Figure 21.7 This satellite is held in orbit by the gravitational attraction between it and the Earth.

Since the late 1950s humans have been able to launch, and to put into orbit around the Earth, objects like the one seen in Figure 21.7. These are known as artificial satellites and are extremely useful. Some satellites are put into a very high orbit above the Earth and are used to help us communicate over large distances, for example, for international phone calls or video links, the internet and so on. Some satellites are put into a much lower orbit and are used to monitor in detail the Earth's surface, such as the temperature of the world's oceans or the progress of forest fires.

COMETS

Comets are large rock-like pieces of ice that orbit the Sun. They have very elliptical (elongated) orbits which at times take them very close to the Sun. At other times they travel close to the very edge of our Solar System.



▲ Figure 21.8 The speed of a comet varies enormously. They travel at their fastest when they are very close to the Sun.

EXTENSION WORK

Although you will not be asked in your exam about the 'tails of comets' it is interesting to know that, close to the Sun, some of a comet's frozen gases evaporate to become gases again, forming a long tail that shines in the sunlight. These tails can be millions of kilometres in length. Perhaps the most famous of the comets is Halley's Comet, which visits our part of the Solar System every 76 years. It was last visible from Earth in 1986.



▲ Figure 21.9 Halley's comet could be last seen from Earth in 1986.

GRAVITATIONAL FIELD STRENGTH

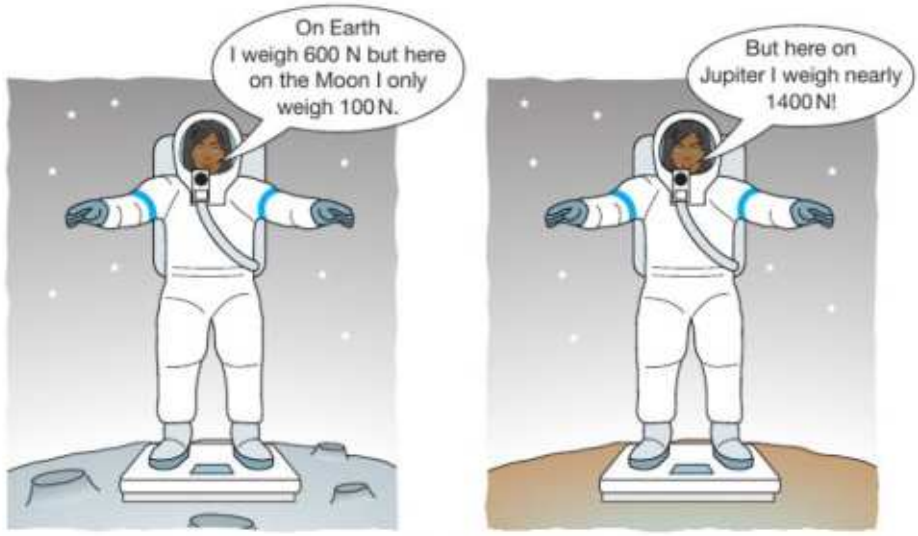
The strength of gravity on a planet or moon is called its gravitational field strength, and given the symbol g. Different planets have different masses and different radii – both of these will affect their gravitational field strengths.

- The larger the mass of a planet the greater its gravitational field strength.
- The larger the radius of a planet the smaller the gravitational field strength at its surface.

The gravitational field strength on the Earth is approximately 10 N/kg while on the Moon it is approximately 1.6 N/kg.

Planet	Diameter compared with the Earth	Mass compared with the Earth	Gravitational field strength / N/kg
Mercury	0.4	0.06	4
Venus	0.9	0.38	9
Earth	1.0	1.0	10
Mars	0.5	0.10	4
Jupiter	11	320	23
Saturn	9	95	9
Uranus	4	15	9
Neptune	4	17.0	11

On the Moon, the gravitational field strength is only one sixth that of the Earth's. This means that on the Moon you would weigh six times less. If however you visited Jupiter you would weigh almost 2½ times more!



▲ Figure 21.10 The difference in one person's weight on the Moon and on Jupiter

ORBITAL SPEEDS OF PLANETS AND SATELLITES

The **orbital speeds** of satellites vary greatly depending on the tasks they are performing. For example, communication satellites are put in high orbits and travel at approximately 3 km/s, while those observing the whole surface of the Earth are put into low polar orbits with speeds of about 8 km/s.

We can calculate the speed of a satellite using the equation:

$$\text{speed, } v = \frac{\text{distance moved, } s}{\text{time taken, } t}$$

The distance moved is the circumference of the circular orbit, r:

distance moved = $2 \times \pi \times$ orbital radius, r

The time period, T, is the time for one complete orbit.

EXTENSION WORK

The orbital period of a communications satellite, and most weather satellites, is 24 hours, and it always remains above the same part of the Earth's surface. It is said to be 'geostationary'.

REMINDER

Remember to use the same units throughout your work. Distances here are likely to be given in kilometres and so must be converted into metres. In this example, you must multiply both 8.2 km and 6600 km by 1000. Times given in hours and minutes need to be converted into seconds.

So:

$$\text{orbital speed, } v = \frac{2 \times \pi \times \text{orbital radius, } r}{\text{time period, } T}$$

$$v = \frac{2 \times \pi \times r}{T}$$

The same equation can be used to calculate the speeds of the planets, where r is the average distance from the Sun.

EXAMPLE 1

Calculate the speed of a satellite that is orbiting 200 km above the Earth's surface and completes one orbit in 1 h 24 min. The radius of the Earth is 6400 km.

The radius of the orbit is measured from the centre of the Earth – that is, it is the radius of the Earth plus the height of the orbit above the Earth's surface.

radius of orbit, r = 200 km + 6400 km
= 6600 km
= 6 600 000 m

orbital period, T = (60 min + 24 min) × 60 seconds
= 5040 seconds

$$\text{orbital speed, } v = \frac{2 \times \pi \times r}{T}$$

$$= \frac{2 \times \pi \times 6\,600\,000 \text{ m}}{5040 \text{ s}}$$

$$= \frac{41\,500\,000 \text{ m}}{5040 \text{ s}}$$

= 8200 m/s or 8.2 km/s

CHAPTER QUESTIONS

More questions on motion in the Universe can be found at the end of Unit 8 on page 706.

SKILLS CRITICAL THINKING

1 a What is the name of the force that keeps all the planets of the Solar System in orbit around the Sun?

b What two factors determine the size of this force on the surface of a planet.

c Describe one difference between the orbits of Mercury and Neptune. Give one reason for this difference.

d Describe how the speed of a comet changes as it orbits the Sun.

2 Describe the differences between the orbits of a moon, a planet and a comet.

SKILLS PROBLEM SOLVING

HINT

Convert the time period into hours.

3 A satellite is in an orbit 35 786 km above the surface of the Earth. The radius of the Earth is approximately 6400 km. The satellite is moving at 3.07 km/s.

a How long does the satellite take to orbit the Earth once?

SKILLS REASONING

b What do you notice about the time period of this satellite?

SKILLS PROBLEM SOLVING

4 If the Earth is approximately 150 million km from the Sun calculate the speed at which the following planets are moving around the Sun. The information you need is given in the table on page 697.

a Earth b Jupiter

22 STELLAR EVOLUTION

The Universe is mainly empty space within which are scattered large numbers of galaxies. Astronomers (scientists who study space and the Universe) believe that there are billions of galaxies in the Universe. The distances between galaxies are millions of times greater than the distances between stars within a galaxy. The distances between the stars in a galaxy are millions of times greater than the distances between planets and the Sun.



▲ Figure 22.1 Photograph of galaxies of the Universe taken by the Hubble space telescope

LEARNING OBJECTIVES

- Know that the Sun is a star at the centre of our Solar System
- Know that the Universe is a large collection of billions of galaxies; galaxies are a large collection of billions of stars; our Solar System is in the Milky Way galaxy
- Understand how stars can be classified according to their colour
- Know that a star's colour is related to its surface temperature
- Describe the evolution of stars of similar mass to the Sun through the following stages:
  - nebula
  - star (main sequence)
  - red giant
  - white dwarf
- Describe the evolution of stars with a mass larger than the Sun

THE MILKY WAY

Our nearest star is the Sun. It is approximately 150 million kilometres from the Earth. Its surface temperature is approximately 6000 °C and temperatures within its core are about 15 000 000 °C. Attractive gravitational forces between stars cause them to group together in enormous groups called galaxies. Galaxies consist of billions of stars. Our galaxy is a **spiral galaxy** called the Milky Way. We are approximately two-thirds of the way out from the centre of our galaxy along one of the arms of the spiral.



▲ Figure 22.2 Our galaxy, the Milky Way



▲ Figure 22.3 Our galaxy takes the shape of a spiral, like the one shown here.



▲ Figure 22.4 The colour of the light emitted by this piece of iron tells us how hot it is.

CLASSIFYING STARS

Even within our galaxy we can see a wide variety of stars (Figure 22.2).

Looking up into a clear night sky, especially if we use a telescope, we can see that stars are not all identical. They have different colours, different levels of brightness and appear to be different sizes. Scientists who study the stars in detail have created classes or star groups based upon these similarities and differences.

Why are some stars white, some red and others yellow? Surprisingly we can find the answer to this question in a traditional blacksmiths. To shape a piece of iron without it breaking the iron must be very hot. A skilled blacksmith will know when the temperature of the iron is high enough simply by taking it out of the furnace (very hot oven) and looking at its colour. If it is glowing white or bright orange it is very hot. If it is a dull red it is much cooler and not ready to be shaped.

In a similar way the colours of stars tell us about their temperatures. A very hot star emits more blue in its spectrum and therefore looks blue, a medium star like our Sun looks yellow and cooler stars appear red.

EXTENSION WORK

Scientists often subdivide these groups into 10 smaller groups by giving them a number between 0 and 9. Our Sun is classified as G2 – that is, it is two-tenths along from a G star towards a K star. (You will not be tested on this in your exam.)

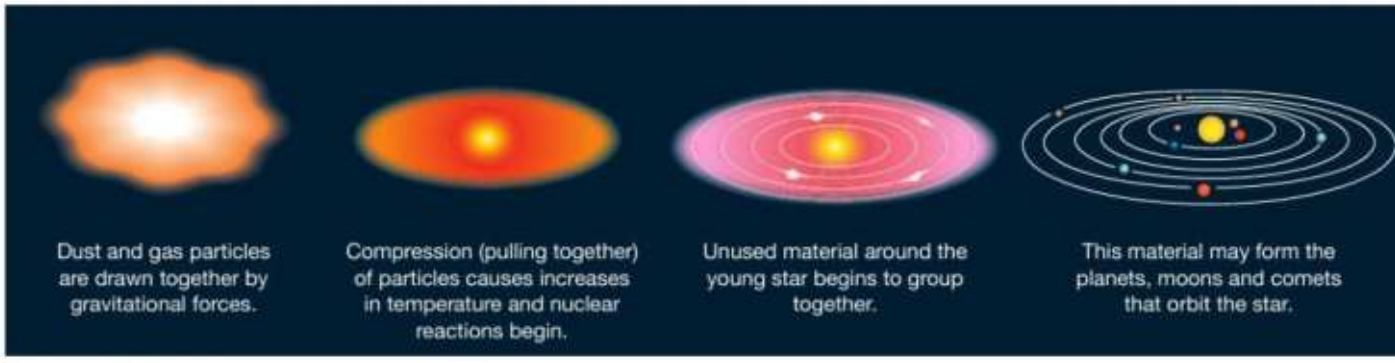
Using the colours of stars and their surface temperatures, scientists have created seven different groups of stars. These groups are called O, B, A, F, G, K, M. O and B are the hottest stars and K and M the coolest.

Star classification	Surface temperature / K	Colour
O	more than 33 000	blue
B	33 000–10 000	blue-white
A	10 000–7500	white
F	7500–6000	yellow-white
G	6000–5200	yellow
K	5200–3700	orange
M	3700–2000	red

REMINDER

The brightness of a star depends on:
- the distance the star is from the Earth
- the luminosity of the star – that is, how much energy is transferred from the star each second.

THE BIRTH OF A STAR



▲ Figure 22.5 Birth of a solar system

Stars like our Sun are formed from large clouds of dust and gas particles we call nebulae or stellar nebulae. These particles are drawn together over a very long period of time by gravitational forces. The particles are pulled together so tightly that there is a very large increase in temperature and pressure. As a result of this nuclear fusion reactions begin. Hydrogen nuclei join together to make larger nuclei and huge amounts of energy is transferred thermally and by radiation (light). This incredibly hot ball of gas is a very young star.

THE LIFE OF A STAR

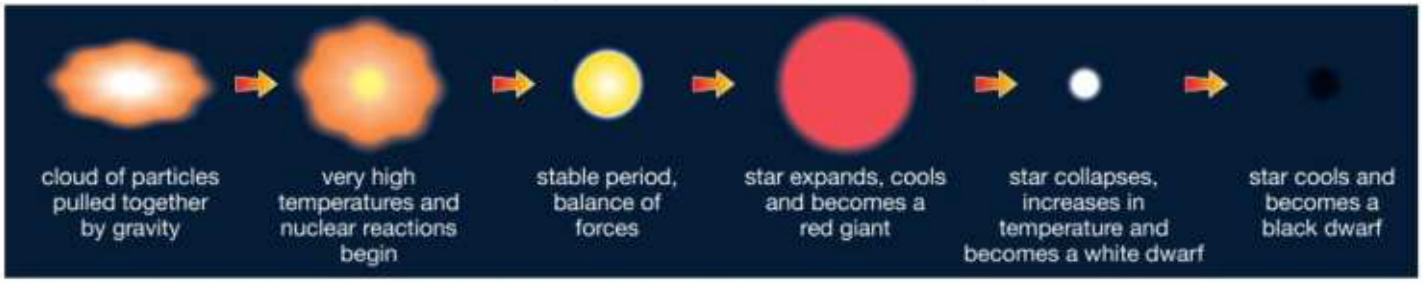
The appearance of a star changes gradually with time. These changes follow a pattern.

When a star first forms, gravitational forces are pulling particles together. Then when nuclear reactions begin, the high temperatures create forces that try to push the particles apart – that is, make the gases expand. When these two forces are balanced, the star is said to be in its main stable period. A star in this main stable period is referred to as a main sequence star (you will learn why later). This period can last for many millions of years. At the moment our Sun is in this stable period.

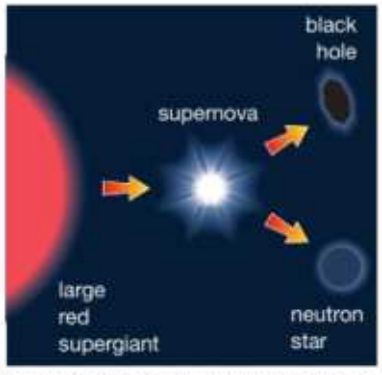
Towards the end of this stable period, there are less hydrogen nuclei and eventually the hydrogen fusion reactions stop. Gravitational forces are now the largest forces and compress the star. As the star shrinks in size there is a large increase in temperature. So high that fusion reactions between helium nuclei begin. The energy released by these reactions causes the star to expand to many times its original size. As it expands it becomes a little cooler and more of its light energy is emitted in the red part of the spectrum. The star is changing into a red giant.

Sometime later when most of the helium nuclei have fused (joined) together, new nuclear reactions begin, but now the compressive or squashing forces are larger and the star begins to get smaller or contract. This contraction causes an increase in temperature so the star again changes colour. It now emits more blue and white light. It has changed into a white dwarf star. The matter from which white dwarf stars are made is millions of times more dense than any matter found on the Earth.

Finally as a white dwarf star cools it changes into a cold black dwarf star.



▲ Figure 22.6 The life-cycle of stars with a mass similar to that of our Sun



▲ Figure 22.7 The final stages for stars with masses much greater than our Sun

A star that is much larger than our Sun may follow a slightly different path at the end of its life. After the stable period it will expand into a large red supergiant. At the end of this period, as it contracts it becomes unstable. It explodes throwing dust and gas into space to form a new stellar nebula. This exploding star is called a supernova. Any matter remaining will form a very dense neutron star. If the neutron star has a mass that is approximately three times greater than that of our Sun or more, it collapses further to become a black hole.

EXTENSION WORK

The gravitational field of a black hole is so strong that even light is unable to escape from it. This is why they are called 'black holes'.
All the elements in the periodic table up to iron are formed in stars but elements heavier than these are only formed in supernova explosions.

CHAPTER QUESTIONS

More questions on stars and their life cycles can be found at the end of Unit 8 on page 706.

SKILLS CRITICAL THINKING

1 a What do we call a large group of stars?
b Why do these groups form?
c What is the name of the group where we live?
d How many other groups of stars do we think exist in the Universe?

SKILLS ANALYSIS

2 Using the table on page 703 answer the following questions.
a Describe two properties of stars that belong in classes B and K.
b To which group does a star belong if its surface temperature is 2500 K?
c To which two groups might a star belong if it is emitting a lot of yellow light?
d What range of surface temperatures might this star have?

SKILLS CRITICAL THINKING

3 Explain the difference between the apparent and absolute brightness of a star.

4 Describe the different stages of a life of a star that is much more massive than our Sun.

5 a What is a supernova?
b Under what conditions does a supernova occur?

UNIT QUESTIONS

SKILLS CRITICAL THINKING 4th **1**

a Which of the following statements is incorrect?

A Gravitational forces keep our Moon in orbit around the Earth.

B Comets and moons orbit planets.

C Planets orbit the Sun.

D Artificial satellites orbit a planet. **(1)**

SKILLS REASONING 3rd

b Which of the following sequences might be followed by a star that has a mass much larger than our Sun?

A main sequence, stellar nebula, red giant, white dwarf

B stellar nebula, main sequence, red supergiant, black hole

C stellar nebula, main sequence, white dwarf, black hole

D main sequence, red giant, neutron star, white dwarf **(1)**

SKILLS CRITICAL THINKING 5th

c Which are the most common reactions that take place in the core of a star that is in the main sequence?

A nuclear fission reactions between helium nuclei

B nuclear fission reactions between hydrogen nuclei

C nuclear fusion reactions between helium nuclei

D nuclear fusion reactions between hydrogen nuclei **(1)**

d Which of the following observations does not support the Big Bang theory?

A cosmic microwave background radiation

B blue-shift in the spectra of galaxies

C red-shift in the spectra of galaxies

D accelerating galaxies **(1)**

(Total 4 marks)

6th **2**

Copy and complete the following passage about gravitational forces, filling in the spaces.

Gravitational forces cause planets and _____ to _____ the Sun. The planets _____ to the Sun, for example, _____ and _____, experience the _____ forces and so have the most _____ orbits. The planets _____ from the Sun, for example, _____ and _____, experience the _____ forces and so have the least _____ orbits. The shape of a planet's orbit is not quite _____. It is _____.

All objects that orbit a planet are called _____ but natural ones are called_____.

(Total 16 marks)

SKILLS PROBLEM SOLVING, ANALYSIS 5th **3**

A man has a mass of 80kg. On the Earth he weighs 800N. Using the table on page 699 calculate the weight of this man on the surface of:

a Venus **(3)**

b Mars **(3)**

c Neptune. **(3)**

(Total 9 marks)

SKILLS PROBLEM SOLVING

4 Calculate the speed of a satellite that is orbiting 250 km above the Earth's surface and completes one orbit in 2 hr.

(Total 5 marks)

SKILLS ANALYSIS

5 The table below contains information about some of the planets in our Solar System.

Planet	Surface gravity compared with the Earth	Distance from Sun compared with the Earth	Period / Earth years
Mercury	0.4	0.4	0.2
Venus	0.9	0.7	0.6
Mars	0.4	1.5	1.9
Jupiter	2.6	5.0	12
Saturn	1.1	9.5	30

a Name three planets that have a weaker gravitational pull on their surface than there is on Earth. **(1)**

b How long is a year on Saturn? **(1)**

HINT

circumference of a circle = $2\pi r$

SKILLS PROBLEM SOLVING

c If the distance from the Earth to the Sun is 150 million kilometres, calculate the distance of Saturn from the Sun. **(2)**

d Assuming that the orbital path for Saturn is circular, calculate its orbital speed in km/s. **(3)**

(Total 7 marks)

SKILLS INTERPRETATION

6 **a** Draw a diagram to show the shape of the orbit of a comet around the Sun. **(2)**

SKILLS REASONING

b Describe and explain how the speed of a comet changes as it travels around its orbit. **(4)**

(Total 6 marks)

APPENDIX A: PERIODIC TABLE

Period	Group 1	Group 2										Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
1	1 H Hydrogen 1																4 He Helium 2
2	7 Li Lithium 3	9 Be Beryllium 4										11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
3	23 Na Sodium 11	24 Mg Magnesium 12										27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
4	39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	63.5 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
5	85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	(98) Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
6	133 Cs Caesium 55	137 Ba Barium 56	■	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	(209) Po Polonium 84	(210) At Astatine 85	(222) Rn Radon 86
7	(223) Fr Francium 87	(226) Ra Radium 88	■ ■	(267) Rf Rutherfordium 104	(268) Db Dubnium 105	(269) Sg Seaborgium 106	(270) Bh Bohrium 107	(277) Hs Hassium 108	(278) Mt Meitnerium 109	(281) Ds Darmstadtium 110	(282) Rg Roentgenium 111	(285) Cn Copernicium 112	(286) Nh Nihonium 113	(289) Fl Flerovium 114	(290) Mc Moscovium 115	(293) Lv Livermorium 116	(294) Ts Tennessine 117	(294) Og Oganesson 118

a
X
Name
b

a = relative atomic mass
X = atomic symbol
b = atomic number

(Masses in brackets are the mass numbers of the longest-lived isotope)

■	139 La Lanthanum 57	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(145) Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	163 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
■	(227) Ac Actinium 89	232 Th Thorium 90	231 Pa Protactinium 91	238 U Uranium 92	(237) Np Neptunium 93	(244) Pu Plutonium 94	(243) Am Americium 95	(247) Cm Curium 96	(247) Bk Berkelium 97	(251) Cf Californium 98	(252) Es Einsteinium 99	(257) Fm Fermium 100	(258) Md Mendelevium 101	(259) No Nobelium 102	(266) Lr Lawrencium 103

APPENDIX B: COMMAND WORDS

Command word	Definition
Add/Label	Requires the addition or labelling of a stimulus material given in the question, for example labelling a diagram or adding units to a table.
Calculate	Obtain a numerical answer, showing relevant working.
Comment on	Requires the synthesis of a number of variables from data/information to form a judgement.
Complete	Requires the completion of a table/ diagram.
Deduce	Draw/reach conclusion(s) from the information provided.
Describe	To give an account of something. Statements in the response need to be developed, as they are often linked but do not need to include a justification or reason.
Determine	The answer must have an element that is quantitative from the stimulus provided, or must show how the answer can be reached quantitatively. To gain maximum marks, there must be a quantitative element to the answer.
Design	Plan or invent a procedure from existing principles/ideas.
Discuss	Identify the issue/situation/problem/ argument that is being assessed within the question. Explore all aspects of an issue/situation/ problem/ argument. Investigate the issue/situation etc. by reasoning or argument.
Draw	Produce a diagram either using a ruler or freehand.
Estimate	Find an approximate value, number or quantity from a diagram/given data or through a calculation.
Evaluate	Review information (for example, data, methods) then bring it together to form a conclusion, drawing on evidence including strengths, weaknesses, alternative actions, relevant data or information. Come to a supported judgement of a subject's quality and relate it to its context.

Command word	Definition
Explain	An explanation requires a justification/ exemplification of a point. The answer must contain some element of reasoning/justification – this can include mathematical explanations.
Give/State/ Name	All of these command words are really synonyms. They generally all require recall of one or more pieces of information.
Give a reason/ reasons	When a statement has been made and the requirement is only to give the reason(s) why.
Identify	Usually requires some key information to be selected from a given stimulus/resource.
Justify	Give evidence to support (either the statement given in the question or an earlier answer).
Plot	Produce a graph by marking points accurately on a grid from data that is provided and then draw a line of best fit through these points. A suitable scale and appropriately labelled axes must be included if these are not provided in the question.
Predict	Give an expected result.
Show that	Verify the statement given in the question.
Sketch	Produce a freehand drawing. For a graph, this would need a line and labelled axes with important features indicated. The axes are not scaled.
State what is meant by	When the meaning of a term is expected but there are different ways for how these can be described.
Suggest	Use your knowledge to propose a solution to a problem in a novel context.
Verb proceeding a command word	
Analyse the data/ graph to explain	Examine the data/graph in detail to provide an explanation.
Multiple-choice questions	
What, Why	Direct command words used for multiple-choice questions.

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APPENDIX C: PHYSICAL FORMULAE

1 the relationship between average speed, distance moved and time taken:

$$\text{average speed} = \frac{\text{distance moved}}{\text{time taken}}$$

2 the relationship between force, mass and acceleration:

force = mass × acceleration

3 the relationship between acceleration, change in velocity and time taken:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

4 the relationship between momentum, mass and velocity:

momentum = mass × velocity

momentum = $m \times v$

5 the relationship between density, mass and volume:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

6 the relationship between work done, force and distance moved:

work done = force × distance moved

7 the energy relationships:

energy transferred = work done

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{speed}^2$$

gravitational potential energy = mass × g × height

8 the relationship between mass, weight and gravitational field strength:

weight = mass × gravitational field strength

9 the relationship between an applied force, the area over which it acts and the resulting pressure:

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

10 The relationship between the moment of a force and its perpendicular distance from the pivot:

moment = force × perpendicular distance from the pivot

11 the relationship between charge, current, voltage, resistance and electrical power:

charge = current × time

voltage = current × resistance

electrical power = voltage × current

12 the relationship between speed, frequency and wavelength of wave:

wave speed = frequency × wavelength

13 the relationship between turns and voltage for a transformer:

$$\frac{\text{input (primary) voltage}}{\text{output (secondary) voltage}} = \frac{\text{primary turns}}{\text{secondary turns}}$$

14 the relationship between refractive index, angle of incidence and angle of refraction:

$$n = \frac{\sin i}{\sin r}$$

15 the relationship between refractive index and critical angle:

$$\sin c = \frac{1}{n}$$

16 the relationship for efficiency:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

17 the relationship for pressure difference:

$$\text{pressure difference} = \text{height} \times \text{density} \times \frac{\text{gravitational}}{\text{field strength}}$$

$p = h \times p \times g$

18 input power = output power

$V_p I_p = V_s I_s$

for 100% efficiency

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APPENDIX D: PHYSICAL QUANTITIES

Fundamental physical quantities

Physical quantity	Unit(s)*
length	**metre (m)** kilometre (km) centimetre (cm) millimetre (m)
mass	**kilogram (kg)** gram (g) milligram (mg)
time	**second (s)** millisecond (ms)
temperature	**Kelvin (K)** degrees Celsius/°C
current	**ampere** or **amp (A)** milliampere or milliamp (mA)

*SI base units are shown in bold.

Derived quantities and units

Physical quantity	Unit(s)
acceleration	m/s^2
area	cm^2 m^2
density	kg/m^3 g/cm^3
electrical charge	coulomb (C)
electrical current	ampere (A)
energy (work)	joule (J) kilojoule (kJ) megajoule (MJ)
frequency	hertz (Hz) kilohertz (kHz)
force	newton (N)
gravitational field strength	N/kg
moment of a force	Nm Ncm
momentum	kg m/s
potential difference (voltage)	volt (V) millivolt (mV)
power	watt (W) kilowatt (kW) megawatt (MW)
pressure	pascal (Pa or N/m^2) N/cm^2
radioactivity	becquerel (Bq)
resistance	ohm (Ω)
speed/velocity	m/s km/h
volume	cm^3 m^3 litre (l) millilitre (ml)

All the units used in science are defined by the Système International d'Unités: SI units.

You will, of course, find measurements of units made in subdivisions and multiples of the base unit. For example, the subdivisions of the kilogram are grams (g) and milligrams (mg). Metres are subdivided into centimetres (cm) and multiplied into kilometres (km). You will also be familiar with other units for time: minutes, hours, days and years, and so on. You will need to take care to convert units in calculations to the base units of kg, m and s when you meet these subdivisions and multiples.

EXAMPLE

Car speedometers (an instrument in a vehicle that shows how fast it is going) read in km/h. Calculate the equivalent speed in m/s of a car travelling at 40 km/h.

There are 1000 metres in a kilometre so 40 km = 40 000 m.

An hour is 3600 seconds, so the car travels 40 000 m in 3600 s.

In one second the car will travel $\frac{40\,000\text{ m}}{3600\text{ s}}$

so 40 km/h = 11.1 m/s



Usain Bolt, current world record holder for the 100 m sprint, averaged 10.43 m/s over his record-breaking 100 m.

APPENDIX E: EXPERIMENTAL AND INVESTIGATIVE SKILLS

This appendix is designed to help you gain the 20% of marks allotted to the questions on experimental skills. These skills are tested in all three Science exam papers, mixed up with theory questions. The main chapters in this book contain descriptions of various experiments and it might be helpful to look back at these as well. In the exams you will be asked questions based on these, although the apparatus shown may be slightly different. However, you will also be given questions about unfamiliar investigations. Don't be worried by these – you are not expected to have carried them out, just to be able to apply your knowledge and understanding to interpret experimental design or to analyse data.

Questions in the exams will generally cover the following areas:

- understanding safety precautions
- describing the method for an investigation
- recognising apparatus and understanding how to use it
- taking measurements
- manipulating data, recording results in tables
- plotting graphs
- analysing results
- evaluating data
- understanding experimental design
- planning experiments.

Your investigative skills will be tested by some of the questions in your examinations. This section summarises some of the skills you may be asked about.

1. SAFETY PRECAUTIONS

Before starting a particular experiment, you need to consider what risks are involved in the experiment and which safety precautions are needed.

The obvious precaution is to wear eye protection. That's true of most practical work; eye protection must be worn whenever chemicals or Bunsen burners are used. However, you might be asked a question that says 'Apart from wearing eye protection, explain a safety precaution that you would need to take in doing this experiment. (2 marks)'. Notice the word 'explain' in the last sentence. 'Explain' means that, as well as giving a precaution, you have to give a reason for it. Look at the number of marks available. If there is more than 1 mark, you have to give more than one piece of information.

Some examples of safety precautions, and the reason they are taken, are:

Presence of...	Precaution	Reason
biological material, e.g. plants, soil, etc.	wash hands after handling biological material	to avoid contamination
flammable liquid, e.g. ethanol	keep flammable liquids such as ethanol away from a naked flame	to avoid the ethanol catching fire
any especially fragile apparatus, e.g. pipette, thermometer, microscope cover slips, etc.	take care with fragile glassware	to avoid cutting yourself
electrical apparatus, e.g. a microscope with built-in lamp	do not touch electrical apparatus with wet hands; make sure you are using a low-voltage electricity source	to avoid getting an electric shock
test tube of water	use a water bath to heat a test tube of water, rather than heating it directly in a Bunsen flame	to avoid the heated liquid jumping out of the tube
springs, wires or elastic bands	wear eye protection	to avoid stretching wires or other objects that might break and spring back
poisonous gas, e.g. chlorine	do the experiment in a fume cupboard	to avoid poisoning yourself with the chlorine
corrosive liquid, e.g. acid or sodium hydroxide solution	wear gloves	to avoid burning yourself on the corrosive acid
any hot liquid or apparatus	take care not to touch	to avoid burning yourself

Here are some other things you should think about:

- if you are using weights, make sure they cannot fall and land on your feet
- make sure any clamp stands are fastened to the bench so they cannot overbalance
- if you are using water, make sure that any spills are mopped up so you do not slip
- if you are projecting (firing) an object such as a ball bearing or an arrow make sure that no one is in the area and that an adequate absorbent target is in place
- if you are describing the use of radioactive materials make sure you know how they should be handled and stored safely
- if you are timing the descent of an object such as a model parachute make sure that any chairs or other furniture are out of the way.

Remember that most investigations and practicals are quite safe, and so safety precautions can also refer to care of the apparatus. For example:

- not stretching a spring too far so that it goes beyond its elastic limit
- if you are using electricity to heat something such as fuse wire, use a heatproof mat to protect the bench and do not touch hot wires.

2. RECOGNISING APPARATUS AND DEMONSTRATING AN UNDERSTANDING OF HOW TO USE THEM

One of the simplest types of question in the exams will require you to recognise common pieces of laboratory apparatus, such as a Bunsen burner, thermometer, measuring cylinder and stopwatch. You will also need to recognise particular apparatus such as quadrat, microscope, bench lamp and so on, and how they are used. If you have been able to carry out most of the practical work in the specification, this kind of question is very straightforward, for example:



(a) What is the name of this piece of apparatus? **(1 mark)**

(b) Draw a line on the apparatus to show a volume of 30 cm^3 **(1 mark)**

Use a pencil to draw any lines on diagrams, graphs, etc. Then you can rub it out if you make a mistake. On this measuring cylinder a horizontal line should be drawn halfway between the 20 and 40 cm^3 marks – it's that easy!

3. MEASUREMENTS

Measurements are a key part of investigations, but they do not mean anything unless you also give the units. A length of '15' could mean 15 mm, 15 cm, 15 m, or even 15 km!

If you want to measure the mass of something, you should use a balance. If you want to measure a temperature, you should use a thermometer. When it comes to volumes, however, you are faced with a number of choices of equipment: measuring cylinders of various sizes, burettes, pipettes and gas syringes. It is important to pick the right item.

MEASURING VOLUMES OF LIQUID

Measuring cylinders

Measuring cylinders are acceptable for approximate volumes. Choose the smallest measuring cylinder that will take the volume you need. Trying to measure, for example, 8 cm^3 in a 100 cm^3 measuring cylinder is going to be fairly imprecise. Use a 10 cm^3 measuring cylinder instead.

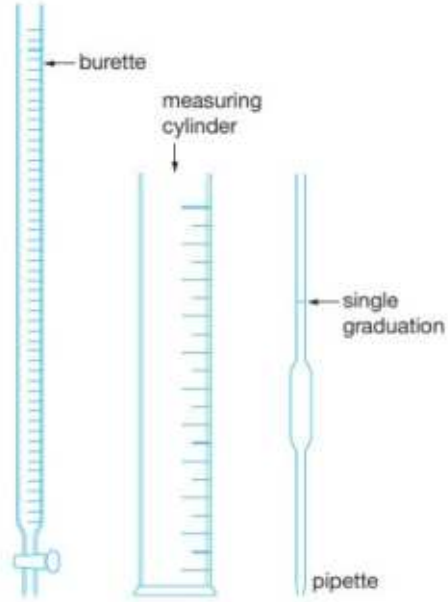
Pipettes

Pipettes will measure the volume printed on them very precisely (typically to within 0.05 cm^3). Common pipettes have volumes of 25 or 10 cm^3, but you might also come across other sizes, such as 5, 20 or 50 cm^3.

Burettes

The most common size of burette will measure variable volumes up to 50 cm^3, and you can take measurements to the nearest 0.05 cm^3.

Note you will never use a beaker or a conical flask to measure the volume of a liquid. They are too imprecise! The precision of a measurement depends on how big the divisions are on an instrument. The smaller the division, the more precise the data.



▲ Figure A1 Devices for measuring volumes of liquid.

MEASURING VOLUMES OF GAS

To measure the volume of a gas you are collecting, you can either use a gas syringe or collect the gas into an inverted measuring cylinder over water. You will find diagrams for both methods on page 430. A gas syringe is more precise and has to be used if the gas is soluble in water.

TAKING READINGS

You take your measurement from the bottom of the meniscus (if you have a liquid), ignoring any liquid that has 'curled up' at the sides (see Figure A2). Edexcel examiners expect you to read a scale to a precision of half the smallest divisions marked on whatever piece of apparatus you are using. If the smallest division is 0.1 cm^3, you are expected to estimate the volume to the nearest 0.05 cm^3 if the meniscus falls between two marks.

The diagram shows a burette reading of 5.85 cm^3. Be very careful to look closely at which way the scale runs. Students might make the mistake of reading this as 6.15 cm^3 because they don't notice that the meniscus is somewhere between 5 and 6 on the scale. Don't simply read from the nearest number, think about what you are doing!



▲ Figure A2 Measuring from the bottom of the meniscus.

RECORDING READINGS

The number you write down should show the degree of precision used. For example, if a burette reading falls exactly on the 11 cm^3 line, you should still record it as 11.00 cm^3 because it was possible to read it to 0.05 cm^3 and your answer wasn't 11.05 or 10.95 cm^3. Recording it as 11 cm^3 implies that you couldn't read it more precisely than to the nearest 1 cm^3.

4. MANIPULATING DATA

Some questions in an exam will involve manipulating data. This means you will be provided with some results from an experiment, and have to process it in various ways, such as:

- putting raw data from a notebook into an ordered table
- counting numbers of observations
- summing totals
- calculating an average
- calculating a missing value
- identifying anomalous results.

For example:
Kirsty monitored how her temperature changed during exercise. She took her temperature before she started the exercise, and every two minutes during the exercise. Here are her results:

Before exercise = 36.4 °C At 12 minutes = 37.6 °C

37.3 °C after 10 mins, 2 mins = 36.8 °C.

After 4 mins = 37.1 °C, 6 min = 37.2 °C, 8 min = 36.9 °C

(a) Organise Kirsty's results into a table. **(4 marks)**

(b) Identify the time when an anomalous temperature reading was taken. **(1 mark)**

Marks for the answer are awarded like this:

(a)

Time / min	Temperature / °C
0	36.4
2	36.8
4	37.1
6	37.2
8	36.9
10	37.3
12	37.6

[Labels: Readings in order **(1 mark)**
Units in header row **(1 mark)**
Two columns **(1 mark)**
Table with time and temperature headings **(1 mark)**]

(b) The anomalous temperature reading was taken at 8 minutes. (Note: 'anomalous' means that the result doesn't fit into the pattern of the other results. In this case the temperature reading at 8 minutes is lower than expected. You might have to circle an anomalous result in a table, or on a graph – see below.)

You may have to calculate totals, averages, or missing values from a table, for example in the table below, which shows the rate of germination when 25 seeds were placed in Petri dishes containing three different solutions:

Solution	Number of seeds germinated				Percentage germinated / %
	Dish 1	Dish 2	Dish 3	Total	
A	24	23	24	?	?
B	20	19	22	61	81.3
C	11	5	?	23	30.7

(a) Calculate the total number of seeds that germinated in dishes 1, 2 and 3 in solution A. **(1 mark)**

(b) Calculate the percentage of seeds that germinated in solution A. Show your working. **(2 marks)**

(c) Calculate the missing value for seeds that germinated in dish 3, solution C. **(1 mark)**

The answers are:

(a) Total = 24 + 23 + 24 = 71

(b) % = (total germinated / total number of seeds) × 100 = (71 / 75) × 100 = 94.7% (Use the same number of decimal places as in the given answers.)

(c) Missing value = 23 – (11 + 5) = 7

This is very straightforward arithmetic: just be careful!

5. PLOTTING GRAPHS

Drawing good graphs

It may sound obvious, but the most important tool you need is a very sharp pencil. You can't draw a good graph with a pen, and, of course, it is impossible to rub out a mistake. In an exam, you are likely to be given a graph grid, possibly with at least one axis unlabelled. Choose a scale that uses as much of the graph paper as possible, but without making it really difficult to plot the points. Label each axis clearly (in ink) and don't forget the units. The independent variable – what you vary – goes on the *x*-axis and the dependent variable – what you measure – goes on the *y*-axis. Plot the points carefully and if any don't seem to be following the general pattern (towards a straight line or a smooth curve), double-check them.

Anomalous results

Sometimes you will see one result that is clearly wrong because it falls well away from the pattern of the others. This is called an **anomalous result** You might be asked to explain what might have caused it. When you are drawing your straight line or curve, you ignore the anomalous point completely.

Your explanation should be as precise as you can make it. Decide whether the point is too high or too low on the graph, then try to think of an experimental reason why that might have happened. It isn't enough to say simply that 'wrong measurements were taken or human error', you have to be much more specific, for example 'too much calcium carbonate was added by mistake, and that produced more carbon dioxide than expected'.

The best way of being sure what the examiners want in this sort of case is to look at mark schemes and Examiners' Reports from past papers. You will find more about this at the end of this appendix.

Straight-line graphs

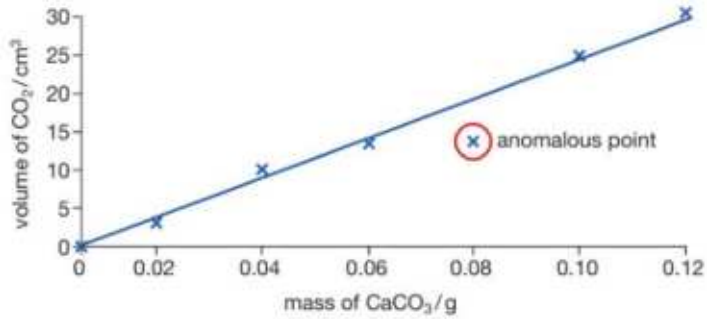
Most (but not all) straight-line graphs that you will get at International GCSE will go through the origin (0, 0). Note that in many cases with 'biological' graphs the line doesn't pass through the 0, 0 coordinates. Does your graph look as if it is going to go through the origin? If so, is it reasonable that it should go through the origin? For example, if you were plotting results from a reaction between calcium carbonate and hydrochloric acid, it would be reasonable that if you didn't use any calcium carbonate, you wouldn't obtain any carbon dioxide. On the other hand, if you were plotting rates of reaction against temperature, it isn't reasonable to assume that a reaction rate would be zero if the temperature was 0 °C.

Suppose you were plotting a graph from an experiment reacting small amounts of calcium carbonate with dilute hydrochloric acid. You are trying to find the relationship between the volume of carbon dioxide produced and the mass of calcium carbonate used. Your table might look like this:

Mass of $CaCO_3$ / g	0.020	0.040	0.060	0.080	0.100	0.120
Volume of CO_2 / cm^3	3	10	13	13	24	31

The graph is plotted with volume of CO_2 (what you measure – dependent variable) on the *y*-axis and mass of $CaCO_3$ (what you change – independent variable) on the *x*-axis. It must also go through (0, 0) as explained above.

Figure A3 is just a sketch graph of these figures. You would need to draw this yourself on graph paper to see exactly how the points should lie.



▲ Figure A3 Volume of carbon dioxide produced versus mass of calcium carbonate used.

There is a best-fit line, and the anomalous point hasn't been included. *It mustn't be – it is obviously wrong!* When you draw a best-fit line, make sure that you have an even spread of points on each side of the line you have drawn. Don't worry if it only goes through one or two of your points. In this case, the only point you are certain about is (0, 0). Your line *must* go through (0, 0) in this particular experiment.

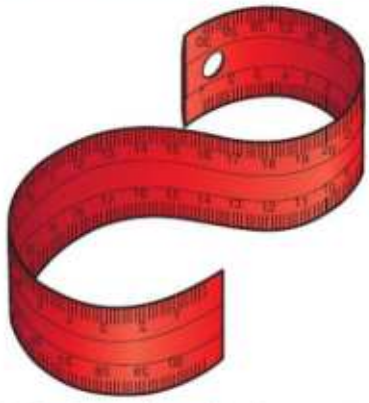
Straight lines m*ust be drawn with a ruler* rather than freehand.

Curved graphs

Exactly the same principles apply, except that it is more difficult to draw a smooth curve than a straight line. The line should still be a best-fit curve and, again, you shouldn't include any anomalous point(s) when you draw it.

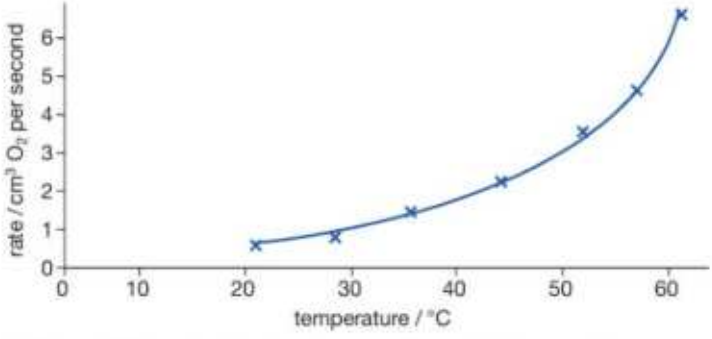
When you are asked to draw a line of best fit, this can be a straight line or a curve.

If you are going to be drawing a lot of graphs in the future (because you are going to do maths or science subjects at a higher level, for example), it is really worth buying a flexible rubber ruler designed for the job. Do an internet search for flexible ruler or 'flexicurve'. These are rulers that can be bent to allow you to draw smooth curves.



▲ Figure A4 A flexible ruler can be used to draw a curve of best fit.

Figure A5 shows how the rate at which oxygen was given off during a reaction (*y*-axis) varied with temperature (*x*-axis). These are imaginary results just to illustrate a point. They don't relate to any real experiment. Don't assume that the curve must go through the origin. In Figure A5, it won't.



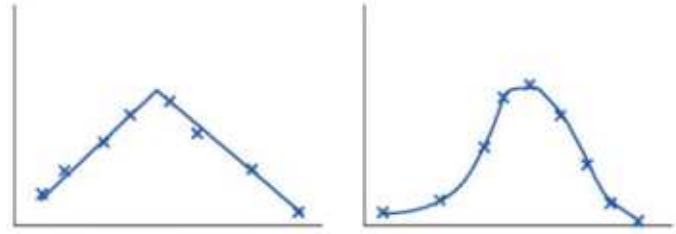
▲ Figure A5 The rate of an imaginary reaction against temperature.

In a case like this, you might be asked how you would modify the experiment to obtain more results between 0 and 20 °C. The obvious thing to do would be to cool the substances you are going to react together before you mix them, by surrounding them with ice. More than once in the past, examiners have commented that students often suggested moving the experiment to a colder climate. You won't get credit for that!

This is an excellent example of why it is essential to look at mark schemes for past papers and read Examiners' Reports. They point out the type of answers they won't accept.

Graphs with unusual shapes

Occasionally, you might be given results that increase for a bit, and then decrease again. The final graph might be two intersecting straight lines or a curve, as shown in Figure A6.



▲ Figure A6 Plotting unusual curves.

You need to look carefully at how the points fall to see which of these you need to draw. You may well find a clue in the question, for example the use of the word 'curve' at some point or 'draw two straight lines'.

After drawing graphs of this kind, you might be asked how you could improve their accuracy. The answer is to take more readings around what is known as the 'turning point' of the graph. With either of these graphs (but especially the curve), what you draw would be more accurate if you had more points around the peak in each case.

Bar charts

Bar charts are easy to draw. Don't forget to label them. These types of graphs are used when the independent variables are not continuous and can only take certain values. For example, in Figure 15.8 on page 420, the number of carbon atoms in an alcohol molecule is an example of a non-continuous variable.

DESCRIBING THE RELATIONSHIPS SHOWN BY A GRAPH

Look back at the straight line graph in Figure A3. What does it show? The correct expression is that 'the volume of carbon dioxide is directly proportional to the mass of calcium carbonate used'. If you just say that 'as the mass of calcium carbonate increases, the volume of carbon dioxide increases', that isn't precise enough, and you may not get the full mark. That faulty statement could equally well describe a curve.

The phrase *directly proportional* means if you double the mass of calcium carbonate, the volume of carbon dioxide produced will double as well. If you triple the mass of calcium carbonate, the volume of carbon dioxide produced also triples. For the relationship between two variables to be directly proportional, the graph must be *a straight line passing through the origin*. If a straight line does not pass through the origin, you should say there is *a linear relationship* between the two variables. If the line has a *positive gradient*, you could say there is a *positive and linear correlation* between the two variables.

The graph in Figure A5 is more difficult to describe. You can start by saying that as the temperature increases, the rate gets faster, but you have to make the point that the line is curved. The examiners commented on a similar question by saying that they were looking for words like 'non-linear'. You could say something like 'The rate increases with temperature'. That suggests a strong upward curve. Alternatively you would have to use

more words and say something like 'the amount that the rate increases for each 10 °C rise in temperature is not constant but increases'. This is a bit more complicated, but it explains what is happening.

6. ANALYSING RESULTS

SIGNIFICANT FIGURES

In some investigations you may have to carry out calculations on your results. For example, if you were investigating how the resistance of a wire depended on its length you would need to calculate the resistance from current and voltage measurements. When you show the results of your calculations, you should always give your result to an appropriate number of significant figures. The following examples should make this clear.

The current and voltage in the first table are both measured to two significant figures (2 sf). In this case, it means that the voltage is accurate to the nearest 0.1 V and the current is accurate to the nearest 0.01 A. When you divide the voltage by the current to get the resistance, you get numbers with lots of decimal places. If you just write down the whole answer as displayed on your calculator, this implies that the answer is more accurate than it is. For example, the last column in the table implies that the resistance value is accurate to the nearest 0.000 000 01 Ω and this is obviously not the case!

Voltage / V	Current / A	Resistance / Ω
2.0	0.24	8.33333333
4.0	0.51	7.84313725
6.0	0.85	7.05882353

You shouldn't quote an answer to more significant figures than the least precise piece of information you are using in the calculation. The results of calculations should be given to the same number of significant figures as in the measurements used to calculate them. If your answer has more significant figures, then you need to round your answer. The table below is a better way of presenting these results.

Voltage / V	Current / A	Resistance / Ω
2.0	0.24	8.3
4.0	0.51	7.8
6.0	0.85	7.1

CALCULATING AVERAGES

If you are calculating the mean average from a number of results that include one or more inconsistent ones, you would normally just take the average of the consistent ones and ignore the anomalous result. For example, with good titration technique you should get results that are consistent to within 0.10 cm^3. Suppose your actual results were:

21.20 21.45 21.30 cm^3

You have two consistent results (21.20 and 21.30), and one that is outside the usual limits of consistency for a titration. Take the average of the two consistent ones (21.25 cm^3) and ignore the other one. You will sometimes be told in these questions what constitutes consistent results, for example 'concordant results are those within 0.10 cm^3 of each other'.

Important! If a question just gives you some numbers to find an average of, without any comment about consistency, just take a simple mean average. For example, one past question asked for an average of 95, 96 and 91. Strictly speaking, you should ignore the 91 value because it is out of line with the other two. The answer given in the mark scheme, however, was 94 (an average of all three). You need to look at a lot of mark schemes and Examiners' Reports to judge how to decide what to do in cases like this.

7. EVALUATING DATA

Evaluation means deciding how accurate and reliable your results are. In the examination, you may be given a set of results and asked to comment on them. You may be asked to identify any results that do not fit the overall pattern. You may be asked to comment on how precise or reliable the evidence is, or how to improve the accuracy or reliability of the results.

Accuracy

Accuracy means how close an experimental result is to its true value. Accuracy of the results depends mainly on the methods you use to obtain them. For example in the photosynthesis experiment on p.127, the method of 'counting bubbles' is probably not a very accurate measure of photosynthesis, for more than one reason. Firstly, the bubbles might be different sizes; secondly, they might contain different mixtures of gases (not just oxygen). A more accurate method would be to collect the gas in a gas syringe, measure its volume, and then analyse it for its oxygen content. Clearly this is beyond what you could be expected to do for an experiment for International GCSE. Sometimes you have to accept that accuracy will be limited by the apparatus available. But you can always comment on how accuracy could be improved, and this might be an answer to part of an exam question.

The accuracy of measurements can be quite poor if human reaction times are involved. For example, if someone is timing how long it takes for a pendulum to complete one swing, they need to start and stop the stop clock as they see the pendulum passing a particular point on its swing. You could suggest two different ways to improve the accuracy of this measurement:

- Use a light gate and data logger to measure the time – this would remove any errors due to human reaction time.
- Measure the time it takes the pendulum to complete 10 swings, and then divide the total time by 10 to find the

time for one swing. There may still be an error due to human reaction time here, but the error will be spread out over many swings, so the error on the time for one swing will be much smaller.

Precision

'Precise' means that things have been measured as accurately possible. Particularly where the quantities being measured are small, the measurements should be taken with the most accurate equipment possible. For example, if the experiment described involved measuring very small currents, you might suggest that the results could have been more precise if a milliammeter had been used instead of an ammeter. Just saying something like 'Take more care with the measurements' will not gain any marks!

Reliability

'Reliable' results mean that if the measurements are repeated, the same result should be obtained. You can see how reliable a set of results are by comparing three or more measurements. If the results are close to each other, then the evidence is probably reliable. Sometimes the word 'concordant' is used to represent data that are consistent with each other.

How can you tell whether your results are consistent and reliable? In the table below, the last row calculates the temperature rise per gram of magnesium used. In this experiment, that result should be consistent if your experiment is reliable.

	Experiment		
	1	2	3
Mass of weighing bottle plus Mg / g	10.81	10.81	10.82
Mass of weighing bottle afterwards / g	10.69	10.69	10.69
Mass of Mg used / g	0.12	0.12	0.13
Initial temperature / °C	17.4	17.5	17.4
Maximum temperature / °C	27.5	27.4	28.4
Temperature rise / °C	10.1	9.9	11.0
Precision check – temperature rise per gram of Mg / °C / g	84.2	(82.5)	84.6

Notice that in the table two values for temperature rise per gram of Mg are in close agreement, but the other one is slightly different. If you were doing calculations from these results, you would omit the results from experiment 2 because they aren't likely to be quite as reliable as the others.

If you are asked how you would improve the reliability of a set of results, say that you would repeat the experiment (possibly more than once), and check the new results for consistency with the old results. If two sets of results agree closely and a third doesn't, then you discard the third set of results.

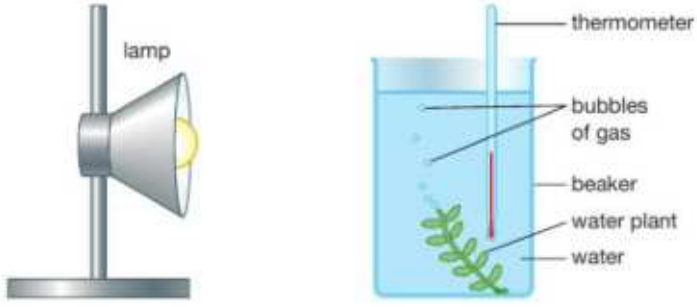
8. EXPERIMENTAL DESIGN

Expect questions on various aspects of experimental design, especially:

- suggesting a suitable Control for an experiment
- the meaning of controlled variables and how to control them
- how to improve accuracy and precision
- how to improve reliability.

(Note that here we are using a capital 'C' for Control, to distinguish it from 'controlled variables')

In a controlled experiment, only one factor is changed at a time. For example, imagine that you are carrying out an investigation into the effect of light intensity on the rate of photosynthesis of a piece of water plant, using this apparatus:



▲ Figure A7 Apparatus measuring the effect of light intensity on the rate of photosynthesis

The factor that you want to change is the light intensity. You can do this by moving the lamp nearer to the beaker, or further away. But it is important that all other factors are kept constant. For example, the temperature must be the same for all light intensities. You can check that it is by reading the thermometer. Moving the lamp closer might make the water in the beaker warmer – you would need to check that this doesn't happen. If the water temperature did increase, it might affect the rate of photosynthesis too. In that case, one of the important variables hasn't been controlled.

Other factors would need to be kept constant too, such as:

1. the size of the water plant (use the same piece throughout the experiment)
2. the wattage of the bulb in the lamp
3. the background lighting in the room (turn the lights off so the only light is from the lamp).

These are called controlled variables, because you, the experimenter, are controlling them (keeping them from changing) so that they can't affect the results. Some experiments involve the use of a Control. This is an experimental set-up where the key factor is missing.

For example, if you were investigating the effect of the enzyme amylase on starch, the experiment would involve mixing amylase with starch to see if the amylase breaks the starch down. It is possible (but unlikely!) that the starch might break down on its own, so a Control would be a tube with just starch, to check whether this happens. (A better control would be starch with boiled amylase, which is as near as possible to the experimental set-up but without the amylase being able to act as an enzyme.)

It is difficult to control variables in fieldwork investigations, such as when sampling with quadrats. For example, imagine you were comparing plants on and off a path using quadrats. Here you can control only certain variables, such as season and time of day when the sampling took place, and the size of quadrat used. But because this is not a laboratory investigation, you have no control over many variables, such as soil composition, water content, amount of trampling etc. All you can do is control the ones you can. However, you might be able to comment on other variables which it is impossible to control, such as the temperature or light intensity.

9. PLANNING AN INVESTIGATION

You may have to give a short account of how you would carry out an investigation. This may be one based on an experiment in the book, or it might involve an unfamiliar situation. Take this example:

Describe an investigation you could carry out to find out the effect of changing the concentration of the enzyme amylase on the rate of starch digestion. **(6 marks)**

This is similar to the experiment described on page 310 in this book, but involves changing the concentration of amylase, rather than the temperature. In any question like this, you have to answer these points.

- What are you going to change?
- What are you going to keep constant (Control) during the experiment?
- What are you going to measure, and how?
- How are you going to check that the results are reliable?

A good answer would be:

> 'I will make up 5 different concentrations of amylase solution (e.g. 1%, 2%, 3%, 4% and 5%) using the same source of enzyme, such as fungal amylase. I will mix 10 cm^3 of each concentration with 10 cm^3 of 1% starch suspension, and time how long it takes for the amylase to digest the starch. To tell when the starch has been digested, I will remove a sample of the mixture at 30-second intervals and add one drop of iodine solution to it. The iodine solution will start off blue-black when the starch is present, but change colour to yellow when the starch has been digested, so I will time how long it takes for this to happen. I will use a water bath to keep the temperature of the reaction mixture at 40 °C. To ensure reliability, I will repeat the experiment three times at each concentration and compare the results.'

The marks (up to a maximum of 6) would be given for points like these:

- using two or more concentrations of amylase (the independent variable)
- using equal volumes of amylase (a controlled variable)
- using the same source of amylase, or explaining its source (a controlled variable)
- using the same concentration or volume of starch (a controlled variable)
- keeping the temperature constant (a controlled variable)
- use of iodine solution to show a colour change from blue-black to yellow
- measuring the time taken for the change (the dependent variable)
- repeating tests at each concentration (for reliability)
- using eye protection while carrying out the experiment.

Some students use the letters CORMS to help them check that they have included everything needed. CORMS stands for:

Change	What will you change? Give the values or range of the independent variable.
Organism	What will you control about the organism used, e.g. the same species of plant, the same batch of yeast, the same age of human subjects.
Repeats	State that you need to carry out repeats, for reliability.
Measure	What will you measure (the dependent variable)? How will you measure it?
Same	What factors will you keep the same (constant)? State at least two controlled variables.

The enzyme investigation above is a straightforward experiment that you could do yourself. However, you might get a question about an investigation that you couldn't do in a school laboratory, like this:

Genetically modified bacteria are grown in industrial fermenters to produce human insulin. Describe an investigation to find out if temperature affects the amount of insulin made by the bacteria. **(6 marks)**

Using the 'CORMS' headings, these features should be covered in your plan:

Change	Use fermenter at different temperatures or suggest a range of temperatures (e.g. 20 °C to 40 °C).
Organism	Use the same species of bacterium at each temperature and the same amount of bacteria.
Repeats	Carry out the experiment several times at each temperature to get reliable results.
Measure	Measure the insulin produced at each temperature. Measure the concentration, mass or volume of insulin produced.
Same	Keep any of these factors constant: pH, nutrients supplied to the bacteria, level of oxygen in the fermenter, sterile conditions.

Write an answer to this question using the CORMS table above to help you.

10. MAXIMISING YOUR SUCCESS

The very besf revising for the exam at the end of your course is to work through past papers set by your examiners, looking especially at the most recent ones. You need to check your answers against the published mark schemes and against the comments in the Examiners' Reports. The Examiners' Reports are particularly useful for these practically-based questions, as what they are looking for isn't always obvious.

This book was written for the new Edexcel International GCSE Double Award specification to be examined for the first time in 2019, and so in the early stages there will be a shortage of past papers tied directly to the new specification. In that case, you will have to look instead at the questions set in similar exams in the past.

BIOLOGY GLOSSARY

abiotic factor physical or chemical factor affecting an ecosystem, e.g. light intensity or temperature

accommodation changes taking place in the eye which allow it to focus on objects at different distances

acid rain rain with a pH less than 5.5, caused by pollutant gases such as sulfur dioxide and nitrogen oxides

active site area on the surface of an enzyme where the substrate attaches and products are formed

active transport movement of molecules or ions against a concentration gradient, using energy from respiration

adaptation feature of an organism that suits its structure to its function

adenosine triphosphate (ATP) chemical present in all cells which acts as an energy 'currency'. ATP is made by respiration and used up by any process that needs a supply of energy

ADH *see* antidiuretic hormone

adrenal glands pair of endocrine glands situated above the kidneys. Secrete adrenaline

adrenaline hormone secreted by the adrenal glands. Stimulates several organs in the 'fight or flight' response

aerobic respiration reaction that releases energy from food. Uses oxygen and produces carbon dioxide and water

agar jelly-like substance used as a culture medium for growing microorganisms

algae photosynthetic protoctists. Mostly unicellular, some multicellular forms (seaweeds)

algal bloom rapid increase in numbers of algal cells in an aquatic habitat. Often caused by eutrophication

alleles different forms of a gene

alveoli (singular = alveolus) microscopic air sacs in the lungs where gas exchange takes place

amino acid one of about 20 different molecules that form the building blocks of proteins

amnion membrane enclosing the embryo during pregnancy

amniotic fluid fluid secreted by the amnion that protects the embryo by acting as a shock absorber

amylase enzyme that digests starch into maltose

anaerobic respiration reaction that releases energy from food, without using oxygen. Produces lactate in mammals, carbon dioxide and ethanol in yeast

anther part of the stamen where pollen grains are produced

antibody protein produced by lymphocytes that binds with foreign antigens as part of the immune response

antigen chemical 'marker' on the surface of a cell that identifies the cell as 'self' or 'non-self'

anus outlet of the gut where faeces is expelled from the body

arteriole small artery

artery (plural = arteries) blood vessel with a thick muscular wall and a narrow lumen, carrying blood away from the heart

artificial insemination (AI) method of selective breeding, where semen is used to make an animal pregnant without sexual intercourse. e.g. using semen from prize bulls to inseminate cows

artificial selection *see* selective breeding

asexual reproduction reproduction that does not involve fusion of gametes. New organisms are produced by part of an organism separating from a single parent

assimilation manufacture of new substances in cells using the products of digestion

ATP *see* adenosine triphosphate

atria (singular = atrium) two upper chambers of the heart where blood enters the heart from the vena cava (right atrium) and pulmonary vein (left atrium)

auxin plant hormone involved in tropisms and other growth responses

axon long extension of a neurone that carries nerve impulses in a direction away from the cell body

bacteria (singular = bacterium) small single-celled organisms with no nucleus

bacteriophage virus that infects bacteria. Used as a vector in genetic engineering

balanced diet diet containing all the necessary food types and in the correct amounts and proportions to keep the body healthy

base (in DNA) one of four nitrogen-containing groups in the DNA molecule, called adenine, thymine, cytosine and guanine. Bases form complementary pairs linking the chains of the double helix

beri-beri a cluster of symptoms caused primarily by thiamine (vitamin B1) deficiency

bicuspid valve valve in the heart between the left atrium and left ventricle. Prevents backflow of blood when the ventricle contracts

bile green liquid made by the liver and stored in the gall bladder. Causes lipids in the gut to form an emulsion, increasing their surface area for easier digestion by enzymes

bile duct tube carrying bile from the gall bladder to the duodenum

bioaccumulation build-up of pollutants such as insecticides in the fatty tissues of an organism

biodiversity the amount of variation shown by organisms in an ecosystem. Biodiversity is a measure of both numbers of species and abundance of each species

biological control use of another organism to control the numbers of a pest species

biomagnification increase in concentration of bioaccumulated substances along a food chain

biomass total mass of organisms, e.g. in an ecosystem

biotechnology use of microorganisms to make useful products

biotic factor biological factor affecting an ecosystem. e.g. food supply, predation

bladder muscular bag that stores urine before its removal from the body

blind spot area of the retina where the optic nerve leaves the eye. Contains no light-sensitive cells, so an image cannot be detected

bronchial tree branching network of air passages in the lungs

bronchioles small air passages leading from the bronchi to the alveoli

bronchitis lung disease caused by irritation of the bronchial tree and infection by bacteria, resulting in breathing difficulties

bronchi (singular = bronchus) tubes leading from the trachea to the lungs

capillary microscopic blood vessel that carries blood through organs and allows exchange of substances between the blood and the cells of the organ

capsule (of bacteria) slime layer covering some bacterial cells. Protects the bacterium and stops it drying out

carbohydrase enzyme that digests carbohydrates

carbohydrate organic compound composed of one or more sugar molecules

carbon monoxide toxic gas present in car exhaust fumes and cigarette smoke

carboxyhaemoglobin substance formed when carbon monoxide combines with haemoglobin, displacing oxygen from the haemoglobin

carcinogen something that causes cancer, e.g. a chemical or radiation

cardiac centre region in the medulla of the brain that controls heart rate

cardiac cycle sequence of events taking place in the heart during one heartbeat

cardiac muscle Specialised muscle making up the heart wall. Able to contract rhythmically without fatiguing

carnivore animal that feeds on other animals

cartilage tough tissue present in several places in the body, such as rings in the trachea and between the bones at a joint

catalyst chemical that increases the rate of a reaction but remains unchanged at the end of the reaction

cell basic structural unit of living organisms

cell membrane thin surface layer around the cytoplasm of a cell. Forms a partially permeable barrier between the cell contents and the outside of the cell

cell wall non-living layer outside the cell membrane of certain types of cell. Made of cellulose (plants and algae), chitin (fungi) or peptidoglycan (bacteria)

cellulose polysaccharide of glucose that forms plant cell walls

central nervous system (CNS) rain and spinal cord

cervix 'Neck' of the uterus

CHD *see* coronary heart disease

chitin substance that makes up the cell wall of fungi and the outside skeleton of insects

chlorophyll green pigment present in chloroplasts, which absorbs light energy during photosynthesis

chloroplast organelle found in some plant cells. The site of the reactions of photosynthesis

cholesterol lipid substance present in the blood and linked to coronary heart disease

choroid dark layer of tissue below the sclera of the eye. Contains blood vessels and pigment cells

chromatid one of two thread-like strands of a replicated chromosome. Each chromatid contains an exact copy of the double helix of DNA. Chromatids become visible at the start of mitosis and meiosis

chromosome thread-like structure found in the nucleus of a cell, made of DNA and protein. Contains the genetic information (genes)

cilia (singular = cilium) microscopic hair-like projections from the surface of some animal cells, such as those lining the trachea and bronchi. Beating of cilia moves mucus and trapped particles towards the mouth

ciliary muscle ring of muscle around the lens of the eye that alters the shape of the lens during accommodation

clone groups of cells, or organisms, that are genetically identical

CNS *see* central nervous system

coleoptile protective sheath covering the first leaves of a cereal seedling. Used in tropism experiments

colon first part of the large intestine, where water is absorbed from the waste material in the gut

community all organisms of all species found in a particular area at a certain time

companion cell specialised cell lying next to a sieve tube in the phloem and controlling its activities

cone (cell) cell in the retina of the eye that is sensitive to different wavelengths of light and results in colour vision

Control part of an experiment which is set up to show that other variables are not having an effect on the outcome of the experiment

controlled variables variables in an experiment other than the independent variable, which are kept constant by the person carrying out the experiment so that they do not affect the results

consumer oganism that eats other organisms

cornea transparent 'window' at the front of the eye that allows light to enter the eye. Also (along with the lens) refracts the light as it enters the eye

coronary arteries small arteries supplying blood to the heart muscle

coronary heart disease (CHD) disease caused by a blockage of the coronary arteries due to a build-up of fatty material. It can cut off the blood supply to the heart and result in a heart attack

coronary veins small veins carrying blood away from the heart muscle

corpus luteum remains of an ovarian follicle after ovulation. Secretes progesterone

cotyledons seed leaves. May act as food store in seed

cross-pollination transfer of pollen from an anther of one plant to a stigma of a different plant of the same species

cuticle thin layer of waxy material covering the epidermis cells of a plant

cutting method of producing new plants by taking a piece of a shoot and planting it in compost. An example of asexual reproduction

cytoplasm jelly-like material that makes up most of a cell

decomposition breakdown of the dead remains of other organisms, helping to recycle nutrients

decomposer organism that feeds by breaking down the dead remains of other organisms. e.g. some bacteria and fungi

denaturing process where the structure of a protein is damaged by high temperatures (becomes denatured). If the protein is an enzyme, it will no longer catalyse its reaction

dendrites fine extensions of the dendrons of a neurone

dendron extension of the cytoplasm of a neurone that carries impulses towards the cell body

deoxyribonucleic acid (DNA) chemical of which genes are made. Double helix composed of deoxyribose sugar, phosphates and four bases

dermis middle layer of the skin containing many sensory receptors

diabetes disease where the blood glucose concentration cannot be properly controlled. Caused by a lack of insulin

diaphragm muscular sheet separating the thorax from the abdomen. Involved in the mechanism that ventilates the lungs

dicot (dicotyledonous plant) plant with two seed leaves

dietary fibre indigestible plant material, mainly cellulose, in the diet. Helps to prevent constipation and bowel diseases

differentiation process taking place during the development of an embryo, where cells become specialised to carry out particular functions

diffusion ovement of molecules or ions down a concentration gradient

digestion process by which food is broken down into simpler molecules that can be absorbed

diploid (number) number of chromosomes found in body cells. Diploid cells contain both chromosomes of each homologous pair.

disaccharide sugar made up of two monosaccharides. e.g. sucrose, which is a disaccharide of glucose and fructose

DNA *see* deoxyribonucleic acid

dominant (allele) allele of a gene that is expressed in the heterozygote

dorsal root part of a spinal nerve that emerges from the dorsal (back) side of the spinal cord

dorsal root ganglion swelling in the spinal nerve that contains the cell bodies of sensory neurones

double circulatory blood circulatory system in mammals, where the blood passes through the heart to the lungs and returns to the heart before passing to the rest of the body

duodenum first part of the small intestine following the stomach

ecosystem community of living organisms together with their non-living environment

effector organ that brings about a response (a muscle or gland)

ejaculation release of semen during sexual intercourse

embryo multicellular structure formed by division of a zygote

emphysema lung disease where the walls of the alveoli break down and fuse together again, forming air spaces with a reduced surface area. It results in breathing difficulties

endocrine gland gland secreting a hormone into the blood stream

enzyme protein that acts as a biological catalyst

epidermis (in plants) outer layer of cells of a leaf or other non-woody parts of a plant

epidermis (in the skin) outer layer of skin, consisting of dead cells

erythrocyte red blood cell

eukaryotic cells that have a nucleus (the cells of all living organisms except bacteria)

eutrophication process where an aquatic habitat receives large amounts of minerals, either naturally or as a result of pollution by sewage or fertilisers

evolution change in form of organisms over the course of time. Process by which species develop from earlier forms during the history of the Earth.

excretion removal from the body of the waste products of metabolism

exocrine gland gland secreting a product through a duct

faeces semi-solid indigestible waste that passes out of the gut via the anus

F_1 generation offspring formed from breeding the parent organisms

F_2 generation offspring formed from breeding individuals from the F_1 generation

fatty acid type of molecule that, with glycerol, is one of the building blocks of lipids

fermentation using the respiration of microorganisms to produce useful products

fermenter a vessel used to grow microorganisms

fertilisation fusion of male and female gametes to form a zygote

fetus unborn offspring of a mammal, in particular an unborn human embryo more than 2 months after fertilisation, when it shows recognisably human features

fibrinogen protein in blood plasma that forms insoluble fibres of fibrin during blood clotting

flaccid condition in a plant cell which has lost internal pressure, so that the cytoplasm no longer pushes against the cell wall

flagellum (plural = flagella) in animal cells such as sperm: tail-like structure that beats from side-to-side, producing movement. In some bacteria: structure with similar function but much smaller and quite different structure

follicle (in ovary) structure in the mammalian ovary that contains a single developing egg cell

food chain flow diagram showing the feeding relationships in an ecosystem

food web diagram showing the way in which several food chains are linked together in an ecosystem

fovea region at the centre of the retina of the eye where there is a high concentration of light-sensitive receptor cells

fructose monosaccharide sugar found in fruits

fruit structure containing a seed or several seeds. Formed from the ovary following fertilisation

FSH *see* follicle stimulating hormone

gall bladder organ that stores bile from the liver

gametes male and female sex cells, formed by meiosis

gene part of a chromosome, the basic unit of inheritance. A length of DNA that controls a characteristic of an organism by coding for the production of a specific protein

genetic engineering techniques used to transfer genes from the cells of a donor organism to those of a recipient

genome the entire DNA of an organism (the amount present in a diploid cell)

genotype alleles an organism has for a certain characteristic

geotropism growth movement of a plant in response to the directional stimulus of gravity

germination sequence of events taking place when the embryo in a seed begins to develop into a young plant

glucagon hormone released by the pancreas. Action of glucagon causes an increase in the concentration of glucose in the blood

glucose mnosaccharide sugar, the main 'fuel' for respiration

glycerol molecule that, along with fatty acids, is a component of lipids

glycogen polysaccharide of glucose that acts as a storage carbohydrate in animals and fungi. Found in liver and muscles

grey matter tissue in the middle of the spinal cord and outer part of the brain. Consists mainly of nerve cell bodies

guard cells pair of specialised cells surrounding a stoma in the epidermis of a leaf. They change shape to open or close the stoma

habitat the place where an organism lives

haemoglobin chemical present in red blood cells that combines with oxygen and carries it around the body

hair erector muscle muscle attached to the base of each hair in the skin. The muscle contracts to pull the hair upright

haploid (number) number of chromosomes found in gametes. Haploid cells contain one chromosome from each homologous pair

hepatic portal vein blood vessel transporting the products of digestion from the ileum to the liver

herbivore animal that feeds on plants

heterozygous genotype with different alleles of a gene, e.g. Aa

histone protein associated with the DNA in a chromosome

homeostasis maintaining constant conditions in the body. Maintaining a constant internal environment

homeotherm animal that maintains a constant body temperature by physiological means (mammals and birds)

homologous pairs pair of chromosomes that carry genes controlling the same features at the same positions on each chromosome. The members of each homologous pair are the same size and shape

homozygous genotype with the same alleles of a gene, e.g. AA or aa

hormone in animals: chemical messenger that travels in the blood. Produced by endocrine glands
In plants: chemical messengers affecting growth

hydroponics crops grown with their roots in a solution of mineral ions rather than in soil

hyphae (singular = hypha) thread-like filaments of cells in fungi

hypodermis layer of skin below the dermis, containing fatty tissue

hypothalamus region at the base of the brain above the pituitary gland. Secretes hormones and monitors various 'drives' such as hunger and thirst

ileum last part of the small intestine, where the products of digestion are absorbed into the blood

immune response mechanism by which the body recognises and deals with an exposure to a pathogenic microorganism. Involves the production of memory cells that respond to a subsequent infection by dividing to give many antibody-producing cells

insulin hormone produced by the pancreas. Action of insulin results in a decrease in the concentration of glucose in the blood

intercostal muscles two sets of antagonistic muscles lying between the ribs. Contract and relax to move the ribs in order to ventilate the lungs

internal environment blood and tissue fluid

invertebrate animal without a vertebral column (backbone)

iris coloured part of the eye visible from the front. Muscles in the iris change the size of the pupil

kingdom major grouping used in classifying organisms, e.g. animals, plants, protoctists

kwashiorkor disease caused by starvation, resulting in body proteins being metabolised

lactate waste product of anaerobic respiration in muscle cells

lactic acid bacteria type of bacteria that produces lactic acid. Used in fermenting milk to make yoghurt and cheese

lacteal structure in the middle of a villus, containing lymph and forming part of the lymphatic system. The lacteal absorbs products of lipid digestion

lactose sugar found in milk. Disaccharide of glucose and galactose

leaching process whereby mineral ions (such as nitrates) are washed out of the soil by rain

ligase enzyme used to join pieces of DNA in genetic engineering

lignin woody material present in the cell walls of some plant cells, such as xylem vessels. Provides strength and makes the walls impermeable to water

limiting factor component of a process or reaction that is in 'short supply', so that it prevents the rate of reaction from increasing

lipase enzyme that digests lipids

lipid fats and oils. Most lipids are composed of fatty acids and glycerol

liver large organ in the abdomen that has many functions, including the storage of glycogen, manufacture of bile, and breakdown of amino acids

lock and key model model of enzyme action where the substrate is the 'key', fitting into the 'lock', which is the active site of the enzyme

lumen space in the middle of a tube such as an artery or a xylem vessel

luteinising hormone (LH) hormone produced by the pituitary gland, which stimulates the release of a mature egg from the ovary (ovulation). Also stimulates the ovary to make oestrogen.

lymphocyte type of white blood cell that produces antibodies

medulla (of brain) part of brain that controls basic body functions such as heart rate and breathing rate

meiosis Type of cell division that produces haploid cells (gametes)

menstrual cycle monthly cycle of events preparing a woman's uterus for the possible implantation of a fertilised egg. Controlled by hormones from the pituitary gland

metabolism chemical reactions taking place inside cells

micropropagation growing plants from small pieces of plant tissue in test tubes under controlled conditions

microvilli minute projections from the surface membrane of some cells, such as those on the surface of the villi of the ileum, where they increase the surface area for the absorption of the products of digestion

minerals elements needed by the body and gained from food but are not present in carbohydrates, lipids or proteins

mitochondrion (plural = mitochondria) organelle that carries out aerobic respiration, releasing energy for the cell. Place where most of the cell's ATP is made

mitosis type of cell division that produces diploid body cells for growth and repair of tissues

monocot (monocotyledonous plant) plant with one seed leaf

monohybrid inheritance involving a single gene

monosaccharide 'Single' sugar such as glucose, which cannot be broken down to give a simpler sugar

motor neurone nerve cell that transmits impulses from the central nervous system to an effector organ

mucus Sticky liquid secreted by cells lining the trachea and bronchi to trap dust and bacteria

multicellular composed of many cells

mutation change in the structure of a gene or chromosome

mycelium network of fungal hyphae

myelin sheath covering made of a lipid material that surrounds an axon. Nerve cells that have a myelin sheath are described as myelinated

natural selection process where certain individuals in a population survive because they are better adapted to their environment. They are more likely to pass on their genes to their offspring. The mechanism of evolution

nerve impulse tiny electrical signal that passes down a nerve cell. Caused by movements of ions in and out of the axon

neuromuscular junction synapse of a nerve cell on a muscle

neurone nerve cell

neurotransmitter chemical released at the end of a neurone by the arrival of a nerve impulse. The neurotransmitter diffuses across a synapse, causing a new impulse in the following neurone

nicotine addictive drug present in tobacco and cigarette smoke

nitrifying bacteria bacteria in the nitrogen cycle that oxidise ammonia to nitrite and then nitrite to nitrate

nitrogen-fixing bacteria bacteria in the nitrogen cycle that convert nitrogen gas into ammonia. They may be free-living in soil, or live in root nodules of legumes

nucleus cell organelle that contains chromosomes. Controls the activities of the cell

oesophagus part of the alimentary canal between the mouth and the stomach

oestrogen female sex hormone secreted by the ovaries. Controls the development of the female sex characteristics and the repair of the uterine lining during the menstrual cycle

optic nerve nerve carrying impulses from the retina of the eye to the brain

organ structure in the body of an animal or plant that is a collection of different tissues working together to perform a function

organ system collection of different organs working together, e.g. the heart and blood vessels of the circulatory system

organelle part of the cell with a particular function, e.g. the nucleus

osmoregulation regulation of salt and water balance in the body

osmosis net diffusion of water molecules across a partially permeable membrane from a solution with a high water potential to a solution with a low water potential

ovary (plural = ovaries) in animals: female reproductive organ that produces ova (eggs).
In plants: female reproductive structure in the carpel of a flower, which contains ovules

oviduct tube leading from the ovary to the uterus. The oviduct is also known as the Fallopian tube.

ovulation release of an ovum from a follicle in the ovary

ovule structure within the ovary in plants. Cells in the ovules divide by meiosis to produce ova.

ovum (plural = ova) female gamete

oxygen debt the volume of oxygen that is needed to completely oxidise the lactate built up during a period of anaerobic respiration

oxyhaemoglobin haemoglobin bound to oxygen

palisade mesophyll layer of cells below the upper epidermis in a leaf. The main site of photosynthesis

pancreas gland discharging into the duodenum. Makes digestive enzymes and is also an endocrine organ, secreting the hormones insulin and glucagon

parasite animal or plant that lives in or on another organism (called the host) and gets nutrients from the host

partially permeable membrane membrane (e.g. the cell surface membrane) that is permeable to some molecules but not permeable to others

pathogen organism that causes disease, e.g. some bacteria

pedigree diagram showing a family tree for an inherited characteristic

penicillin antibiotic obtained from the mould *Penicillium*

pepsin protease enzyme made in the stomach

period common name for loss of blood during the menstrual cycle

peristalsis waves of muscular contraction that push food along the gut

pesticide chemical used to kill pests

phagocyte cell capable of phagocytosis, e.g. some white blood cells

phagocytosis process by which cells engulf and digest material, e.g. white blood cells engulfing bacteria

phenotype how a gene is expressed. The 'appearance' of an organism resulting from its genotype

phloem plant transport tissue responsible for moving the products of photosynthesis from the leaves to other parts of the plant

photosynthesis process carried out in organisms containing chlorophyll. Light energy is used to drive reactions where carbon dioxide and water are used to make glucose and oxygen

phototropism growth movement of a plant in response to a directional light stimulus

pituitary gland gland at the base of the brain which secretes a number of hormones and substances that control the release of hormones from other endocrine glands

placenta organ in mammals which contains blood vessels of the embryo in close proximity to blood vessels of the mother. Allows exchange of gases, nutrients, waste products and other substances between the maternal blood and the embryo's blood

plant growth substances plant 'hormones' that affect various aspects of plant growth

plasmid Small circular piece of DNA found in bacteria and used in genetic engineering

plasmolysed condition of a plant cell that has lost water by osmosis, resulting in the cell contents shrinking and the cell membrane and cytoplasm pulling away from the cell wall

platelets small fragments of cells in blood. Responsible for releasingchemicals involved in blood clotting

pleural cavity space between the pleural membranes

pleural fluid thin layer of liquid filling the pleural cavity

pleural membrane two layers of membrane forming a continuous envelope around the lungs

plumule embryonic shoot of a plant

pollen grain structure in plants that contains the male gamete

pollen tube tube that grows from a pollen grain and down through the style to allow the transfer of the male gamete to the ovule for fertilisation

pollination transfer of pollen from anther to stigma

pollution contamination of the environment by harmful substances that are produced by the activities of humans

polygene name given to a group of several genes working together to determine a characteristic, e.g. height in humans

polygenic inheritance characteristics controlled by two or more genes working together

polysaccharide carbohydrate made of many sugar units, e.g. starch, which is a polysaccharide of glucose

population all the organisms of one species living in a particular habitat at a certain time

predator animal that kills and eats other animals

primary consumer organism that feeds on producers

producer organism that makes its own food, e.g. green plants

progesterone female sex hormone made by the corpus luteum in the ovaries, and later by the placenta. Progesterone causes further thickening of the uterus lining during the menstrual cycle and maintenance of the lining during pregnancy. A drop in levels of progesterone stimulates menstruation

prokaryotic cells of bacteria, which are small and lack a nucleus or membrane-bound organelles

protease enzyme that digests proteins

protein organic substance made of chains of amino acids

protoctist a mixed group of eukaryotic organisms that are not plants, animals nor fungi. Mostly unicellular species

protozoa 'Animal-like' species of protoctists

puberty time when developmental changes take place in boys and girls that lead to sexual maturity

pulmonary circulation circulation of blood from the heart to the lungs via the pulmonary artery and back to the heart via the pulmonary vein

pupil hole in the centre of the iris that allows light to enter the eye

pyramid of biomass diagram in which blocks making up a pyramid represent the total mass of organisms at each trophic level

pyramid of numbers diagram in which blocks making up a pyramid represent the total numbers of organisms at each trophic level

quadrat square used in ecological investigations to sample animals or plants

quaternary consumer organism that feeds on tertiary consumers

radicle embryonic root of a plant

receptor cell or organ that detects a stimulus

recessive allele that is not expressed in the phenotype when a dominant allele of the gene is present (i.e. in the heterozygote)

recombinant DNA DNA made by genetic engineering, by combining DNA from two species of organisms

rectum last part of the large intestine, where faeces is stored

reflex action rapid, automatic, involuntary response to a stimulus

reflex arc nerve pathway of a reflex action

relay neurone short neurone that connects a sensory neurone with a motor neurone in the CNS

reliability (of experimental results) measure of how similar the results are, if the experiment is carried out several times

renal artery blood vessel that supplies blood to a kidney

renal vein blood vessel that takes blood away from a kidney

respiration chemical reaction taking place in cells, where glucose is broken down to release energy

response reaction by an organism to a change in its surroundings

restriction endonuclease *see* restriction enzyme

restriction enzyme enzyme used in genetic engineering to cut out a section from a molecule of DNA

retina inner, light-sensitive layer at the back of the eye

ribosome tiny structure in the cytoplasm of cells, the site of protein synthesis

RNA *see* ribonucleic acid

rod (cell) light-sensitive cell in the retina which works in dim light, but cannot distinguish between different colours

root hairs specialised cells on the surface of a root that take up water and mineral ions from the soil

root nodules swellings on the roots of legumes, containing nitrogen-fixing bacteria

saliva digestive juice secreted into the mouth by the salivary glands. Contains the enzyme amylase

saprotrophic type of nutrition where dead organic material is digested outside the body of the organism by extracellular enzymes. Carried out by fungi and most bacteria

sclera tough outer coat of the eye

scurvy a disease resulting from a lack of vitamin C

secondary consumer organism that feeds on a primary consumer

secondary sexual characteristics changes taking place in the bodies of boys and girls at puberty

secretion release of a fluid or substances from a cell or tissue

seed structure that forms from the ovule following fertilisation. Contains the embryo plant and its food store

selective breeding process where humans cross-breed individual animals or plants that have been chosen because they show certain characteristics. Used to produce domestic animals and crop plants. Also known as artificial selection

self-pollination transfer of pollen from an anther to a stigma of the same flower or to another flower of the same plant

semen mixture of sperm from the testes and fluids from glands. Ejaculated during sexual intercourse

semilunar valves Valves present at the start of the aorta and the pulmonary artery. Prevents backflow of blood when the ventricles relax

sensory neurone nerve cell which carries impulses from a receptor into the CNS

sex chromosomes pair of chromosomes that determine sex in humans. XX in females, XY in males

sexual intercourse insertion of the penis into the vagina, followed by release of semen

sexual reproduction reproduction involving fusion of male and female gametes to form a zygote

shivering rapid, involuntary contractions of skeletal muscles which generates heat when a person is cold

sieve plate specialised end wall of sieve tube, with holes allowing connections between one cell and the next

sieve tube cell found in phloem, consisting of tube transporting the products of photosynthesis

single circulatory blood circulatory system in fish, where the blood passes from the heart to the gills, then to the body before returning to the heart

sperm male gamete of an animal, with a tail for swimming and a head containing the nucleus

sphincter muscle ring of muscle in the wall of an organ, which holds back its contents. E.g. the sphincter muscle at the outlet of the bladder

spongy mesophyll layer of photosynthetic cells below the palisade layer in a leaf. Contains air spaces and is the main gas exchange surface

stamen male reproductive organ in plants, consisting of the anther and a stalk called the filament

starch polysaccharide of glucose that acts as a storage carbohydrate in plants

stem cell cell that can divide several times but remains undifferentiated. Present in the early embryo and in some adult tissues such as bone marrow

stigma part of the carpel of a flower which receives the pollen during pollination

stimulus change in the surroundings of an organism that produces a response

stomata (singular = stoma) pores in the epidermis of a leaf

style part of the carpel of a flower. Stalk connecting the stigma to the ovary, through which the pollen tube grows

substrate molecule upon which an enzyme acts

sucrose disaccharide made from glucose and fructose. The main sugar transported in the phloem of plants

suspensory ligaments fibres between the lens and ciliary body of the eye that hold the lens in position

sweat gland structure in the dermis of the skin that secretes sweat

synapse junction between two neurones

systemic circulation part of a double circulation that supplies blood to all parts of the body except the lungs

tertiary consumer organism that feeds on secondary consumers

test cross cross of an organism showing the dominant phenotype with one showing the recessive phenotype. The F_1 from the cross shows whether the parent is homozygous dominant or heterozygous

testa seed coat

testis (plural = testes) male reproductive organ in animals that produces the male gametes

testosterone male sex hormone, made by the testes. Responsible for the development of the male secondary sex characteristics

thermoregulatory centre part of the brain that monitors core body temperature

thorax (in mammals) chest, which includes the ribcage enclosing the heart and lungs

tissue collection of similar cells working together to perform a function

tissue fluid watery solution of salts, glucose and other solutes. Surrounds all the cells of the body, forming a pathway for the transfer of nutrients between the blood and the cells

trachea 'Windpipe' leading from the nose and mouth to the bronchi

transcription process by which the information in the base sequence of a strand of the DNA is copied into a molecule of mRNA

transgenic organism that has been engineered with a gene from another species

transpiration stream passage of water and minerals through the roots, stem and leaves of a plant

tricuspid valve valve in the heart between the right atrium and right ventricle. Prevents backflow of blood when the ventricle contracts

trophic levels different feeding levels in a food chain

tropical rainforests forests of tall, densely growing, broad-leaved evergreen trees in areas of high yearly rainfall. Rainforests form a belt around the Earth in countries near the Equator and have a very high biodiversity

tropism growth of a plant in response to a directional stimulus

tumour mass of cells produced by mutation and uncontrolled cell division

turgid description of a plant cell with a high internal pressure, so that the cytoplasm pushes against the cell wall

turgor condition of a plant when its cells are turgid

unicellular composed of a single cell

urea main nitrogenous excretory product of mammals

ureter tube carrying urine from the kidney to the bladder

urethra tube carrying urine from the bladder to the outside of the body

vaccination artificially supplying antigens to a person (e.g. as an injection) in order to stimulate an immune response and protect them against a disease-causing pathogen

vacuole membrane-bound space in a plant cell, filled with a solution of sugars and salts called cell sap

vascular bundle xylem and phloem grouped together in a stem or root

vasoconstriction narrowing of blood vessels in the skin. Decreases the blood flowing through the skin to reduce heat loss

vasodilation widening of blood vessels in the skin. Increases the blood flow through the skin to increase heat loss

vector (in genetic engineering) structure which can be used to transfer genes in genetic engineering, e.g. a plasmid

vein blood vessel with a thin muscular wall and a wide lumen, carrying blood towards the heart

ventilation movement of the air in and out of the lungs

ventral root part of a spinal nerve that emerges from the ventral (front) side of the spinal cord

ventricles two lower chambers of the heart, which pump blood out of the heart via the aorta (from the left ventricle) and pulmonary artery (from the right ventricle)

vertebrate animal with a vertebral column or 'backbone'

villi (singular = villus) tiny projections from the lining of the ileum that increase the surface area for the absorption of the products of digestion

viruses very small microorganisms that are not composed of cells. Virus particles consist of genetic material (DNA or RNA) surrounded by a protein coat

vitamins group of chemicals that are obtained from the diet and needed in small amounts to maintain health

water potential measure of the ability of water molecules to move in a solution. Pure water has the highest water potential

white matter tissue in the outer part of the spinal cord and the middle of the brain, consisting mainly of nerve cell axons

wilt changes taking place in a plant when its cells lose too much water and become flaccid. The leaves droop and collapse

xylem transport tissue carrying water and minerals up through a plant from the roots

zygote single cell resulting from fusion of a male and female gamete

CHEMISTRY GLOSSARY

absorb take in (a gas or a liquid)

acid a substance that acts as a source of hydrogen ions (H^+) in solution (Arrhenius theory) or as a proton donor (Brønsted–Lowry theory)

acid rain rain which has a pH of less than about 5.6. It is caused when water and oxygen in the atmosphere react with sulfur dioxide to produce sulfuric acid, or with various oxides of nitrogen, NO_x, to give nitric acid

activation energy the minimum amount of energy required for a collision to be successful, i.e. to result in a reaction

addition a chemical reaction in which one molecule adds to another without taking anything away, to form a single product. For example, when alkenes react with halogens, the halogen atoms add onto the alkene molecule

addition polymerisation polymerisation of monomers containing a carbon–carbon double bond. A large number of monomer molecules add onto each other without anything else being formed

alcohols a homologous series of compounds which all contain an –OH functional group attached to a hydrocarbon chain

alkali metals group 1 elements including lithium, sodium, potassium, rubidium, caesium and francium. Note, hydrogen is not an alkali metal

alkanes a homologous series of similar hydrocarbons in which all the carbons are joined to each other with single covalent bonds. These are saturated compounds with the general formula C_nH_{2n+2}

alkenes a homologous series of hydrocarbons which contain a carbon–carbon double bond. These are unsaturated compounds with the general formula C_nH_{2n}

allotropes different forms of the same element, for example diamond, graphite and C_{60} fullerene are three allotropes of carbon

alloy a mixture of a metal with, usually, other metals or carbon. For example, brass is an alloy of copper and zinc, and steel is an alloy of iron and carbon

amphoteric substances that can react with both acids and bases to form salts

anhydrous without water

anion a negative ion, formed by atoms gaining electrons

anode the positive electrode in electrolysis, which attracts negative anions

aqueous something dissolved in water

array an ordered arrangement of things

ash the soft powder that remains after something has been burned

atom the smallest piece of an element that can still be recognised as that element

atomic number the number of protons in an atom

Avogadro constant the number of ^{12}C atoms in 12 g of ^{12}C (6.02×10^{23} mol^{-1})

balancing the equation a process of putting coefficients in front of formulae so that the same number of atoms of each type is on both side of an equation

barrier method a method of rust prevention by coating iron with paint, oil, grease or plastic, so that oxygen/water cannot reach the iron/steel

base a substance that neutralises acids by combining with the hydrogen ions in them. They are usually metal oxides, hydroxides or ammonia. A soluble base is called an alkali, and it is a substance that acts as a source of hydroxide ions (OH^-) in solution (Arrhenius theory) or as a proton acceptor (Brønsted–Lowry theory)

boiling the change of state from a liquid to a gas. It occurs at the boiling point

bubbling producing bubbles

calorimetry measuring the heat given out or taken in by a chemical reaction

catalyst substance that speeds up a chemical reaction by providing an alternative pathway of lower activation energy. Catalysts are not used up and remain chemically unchanged at the end of the reaction

catalytic converter a device used in cars to convert oxides of nitrogen and carbon monoxide into harmless nitrogen gas and carbon dioxide. It uses platinum, palladium and rhodium as catalysts

cation a positive ion, formed by atoms losing electrons

chemical means methods which involve chemical reactions

chromatogram the adsorbent paper from paper chromatography showing the separation of different coloured substances

coefficient number written in front of formulae in a balanced chemical equation

coil continuous series of circular rings into which something such as wire or rope has been wound or twisted

collision theory states that for a reaction to occur, the reactant particles must collide with each other and the collision needs to have sufficient energy and the correct orientation

combustion a chemical reaction in which a substance reacts with oxygen (burns) to form products and heat

competition reaction displacement reaction between a more reactive metal and the oxide of a less reactive metal

complete combustion occurs when a hydrocarbon burns in sufficient oxygen (burns) and forms carbon dioxide and water as products

compound a substance that forms when two or more elements chemically combine. The elements cannot be separated by physical means

condensation the change of state from a gas to a liquid. It occurs at the condensation point

corrosive a substance which can damage living tissue

covalent bond strong electrostatic force of attraction between the nuclei of the atoms making up the bond and the shared pair of electrons

cracking a process in which long-chain alkanes are converted to alkenes and shorter-chain alkanes. It is carried out using silica or alumina as catalyst at a temperature of 600–700 °C

crude oil formed from the remains of living organisms when their soft tissue was gradually changed by high temperatures and pressures into a thick, black oil. It is a mixture of hydrocarbons

crystallisation a process in which a solute (soluble solid) is obtained from its solvent

damp slightly wet

decomposition reaction a chemical reaction in which a compound is broken down into its elements or simpler compounds

dehydration removal of water

delocalised electrons electrons that are no longer attached to particular atoms or pairs of atoms, but are free to move throughout the whole structure

deposition the change of state directly from a gas to a solid

diatomic a molecule that contains two atoms

diffusion the random movement of particles from an area of high concentration to an area of low concentration

dipping putting something into a liquid and lifting it out again

displacement reaction a chemical reaction in which a more reactive element replaces a less reactive one in its compound

displayed formula a formula that shows all the bonds in a molecule as individual lines. Each line represents a pair of shared electrons in a covalent bond

dot-and-cross diagram a representation of how electrons are arranged in ions or molecules

double bond atoms sharing two pairs of electrons in a covalent bond

dry ice solid carbon dioxide

ductile a property of metal that allows it to be drawn out into wires

electrode a conductor through which electricity is passed into and out of an electrolyte

electrolysis the chemical change caused by passing an electric current through a compound that is either molten or in solution

electron a subatomic particle found in shells (energy levels) outside the nucleus of an atom. It has a relative mass of 1/1836 and a relative charge of 1–. For a neutral atom, the number of electrons = the number of protons = the atomic number

electronic configuration how electrons are arranged in the shells (energy levels) in an atom

electrostatic attraction the force of attraction between something that is positive and something that is negative

element a substance that cannot be split into anything simpler by chemical means. An element contains atoms of the same atomic number

empirical formula gives the simplest whole-number ratio of the atoms present in a compound. It can be worked out from experimental data

endothermic reactions in which heat energy is taken in from the surroundings

enthalpy change the amount of heat energy taken in or given out in a chemical reaction. It has the symbol ΔH

enzymes biological catalysts, usually consisting of proteins

evaporation the change of state from a liquid to a vapour. It occurs at a temperature below the boiling point and only at the surface of the liquid

excess having more than enough of a reactant to react with all of something else

exothermic reactions in which heat energy is given out to the surroundings

fade lose colour and brightness

filtrate the liquid that comes through the filter paper during filtration

filtration a process to separate an insoluble solid from a liquid

fizzing making many bubbles, producing a continuous sound

flash shine suddenly and brightly for a short period of time

flush out force something out

formula a representation of a chemical showing the elements present

forward reaction from reactants to products (the left-to-right reaction)

fossil fuels these include coal, gas and fuels derived from crude oil, which all come from things that were once alive

fractional distillation a process to separate two liquids of similar boiling points, for example ethanol and water or the components of crude oil

fractionating column a piece of equipment used for separating vapours in fractional distillation

freezing the change of state from a liquid to a solid. It occurs at the freezing point

freezing point the temperature at which a substance changes its state from a liquid to a solid

fuel a substance that when burned in oxygen releases heat energy

fume strong-smelling gas or smoke that is unpleasant to breathe in

functional group an atom or a group of atoms that determine the chemical properties of a compound

general formula a formula applicable to all members of a homologous series, for example C_nH_{2n+2} for alkanes and C_nH_{2n} for alkenes

giant a structure in which there are no individual molecules and the bonding extends in all directions. There is no limit to the number of particles present

giant ionic lattice the arrangement of ions in an ionic compound in its solid state

global warming greenhouse gases, including carbon dioxide, trap the heat radiated from the Earth's surface (originally from the Sun) and lead to an increase in the temperature of the Earth and its atmosphere

glow produce a steady light

greenhouse gas gases such as carbon dioxide which can trap heat radiated from the Earth's surface (originally from the Sun)

group a vertical column in the Periodic Table. All elements in the same group have the same number of outer shell electrons

half-equation a balanced symbol equation to describe either oxidation or reduction

halogen group 7 element, including fluorine, chlorine, bromine, iodine and astatine

hammered been hit with a hammer to be forced into a particular shape

homologous series a series of compounds with similar chemical properties because they have the same functional group. Each member differs from the next by $-CH_2-$. The members show a gradation in physical properties

hydrated containing water

hydration the addition of water molecules to an unsaturated molecule, for example converting ethene to ethanol

hydrocarbon molecules containing carbon and hydrogen only

hydrogen bond a special type of intermolecular force found between water molecules and in some other substances

hydrogen halide compound formed between hydrogen and a halogen, with the formula HX where X stands for a halogen atom

hydrogenation the addition of hydrogen molecules to an unsaturated molecule, for example converting ethene to ethane

hydroxonium ion an ion formed when water accepts a proton from an acid. It has the formula H_3O^+

incomplete combustion occurs when a hydrocarbon burns in insufficient oxygen. Water is still formed as a product, but carbon monoxide or carbon are formed instead of carbon dioxide

independent variable what you vary in an experiment

indicator a substance that has different colours depending on the pH

inert unreactive

intermolecular force force of attraction between covalent molecules, much weaker than covalent bonds within the molecules

ion charged particle formed when an atom (or group of atoms) loses or gains electrons

ionic bonding strong electrostatic force of attraction between oppositely charged ions, formed by the transfer of electrons from one atom to another

iron filings small pieces of iron that are used in some chemical experiments

isoelectronic having the same number of electrons

isotopes different atoms of the same element, with the same number of protons but a different number of neutrons. Isotopes have the same chemical properties

kinetic energy a form of energy a substance possesses due to motion

lattice a regular array of particles

litre a unit for volume. One litre = one dm^3

lump a mass of solid without a particular shape

malleable a property of metal which allows it to be hammered into different shapes

mass number the total number of protons and neutrons in the nucleus of an atom

melt the change of state from a solid to a liquid. It occurs at the melting point

melting point the temperature at which a substance changes its state from a solid to a liquid. A pure substance has a fixed melting point but a mixture may melt over a range of temperatures

miscible liquids (or gases) which can mix with each other and form a homogenous mixture

mixture two or more substances not chemically combined that can be separated by physical means

molar enthalpy change the change in enthalpy when 1 mole of a particular reactant reacts

molar mass the mass of 1 mole of a substance

mole a unit of the amount of a substance. A mole of anything contains the same number of particles as there are carbon atoms in 12 g of ^{12}C (6.02×10^{23} particles)

molecular formula shows the actual number of each type of atom present in a molecule (covalent compound) or formula unit (ionic compound)

molecule two or more atoms covalently bonded together. Molecules contain a certain fixed number of atoms

molten liquid state when a solid has melted

monomer molecules which can join up to form a polymer

mono-substitution a substitution reaction in which only one hydrogen atom in an alkane is replaced by a halogen atom

neutralisation reaction a chemical reaction in which acids react with bases or alkalis to produce salts

neutron a subatomic particle in the nucleus of an atom. It has a relative mass of 1 and no charge. Number of neutrons in an atom = mass number – atomic number

noble gas group 0 elements, including helium, neon, argon, krypton, xenon and radon

non-biodegradable cannot be broken down by bacteria or fungi in the environment

non-continuous variable an independent variable which can only take certain values

non-renewable resource a finite resource that cannot be replaced, at least not for millions of years

nucleon number same as mass number

nucleus contains protons and neutrons in an atom

octet the octet rule states that atoms generally lose, gain or share electrons in order to have eight electrons in their outer shell

ore rocks that contain enough of the mineral for it to be worthwhile to extract the metal

organic chemistry branch of chemistry that studies the compounds of carbon except for the very simplest (like carbon dioxide, carbon monoxide, the carbonates and the hydrogencarbonates)

oxidation gain of oxygen or loss of electrons

oxidising agent something that oxidises something else by taking electrons away from it. An oxidising agent is reduced in a chemical reaction

paper chromatography a process to separate a mixture of coloured substances using adsorbent paper

parent acid the acid from which a salt is formed, for example sulfuric acid is the parent acid for sulfates

particle a small object. In chemistry, particle can be used to refer to atoms, molecules, ions or the subatomic particles, including protons, neutrons and electrons

period a horizontal row in the Periodic Table. All elements in the same period have the same number of occupied shells

Periodic Table a table in which elements are arranged in the order of increasing atomic number and in terms of chemical and physical properties

pH scale a scale to measure how acidic or how alkaline a solution is

physical means methods which involve changing temperature, dissolving etc., for example distillation, filtration, use of magnet, chromatography, crystallisation, for separating components of a mixture

plot draw a graph to represent information

plunger a part of a syringe that moves in and out

polar a polar covalent bond is one in which electrons are not equally distributed between the two atoms

polymer a large molecule made when many small molecules (monomers) join together. It consists of many repeat units

polymerisation Joining up of lots of small molecules (monomers) to make one big molecule (polymer)

pop a sudden short sound, often loud

pour make something flow out of a container by holding it at an angle

precipitate a fine solid that is formed by a chemical reaction involving liquids or gases

precipitation reaction a chemical reaction in which a fine solid is formed from liquids or gases

pressure the force acting on something per unit area. Pressure has the SI unit of Pa (N/m^2) and is caused by molecules hitting the walls of their container

proton a subatomic particle in the nucleus of an atom. It has a relative mass of 1 and a relative charge of 1+. Number of protons in an atom = atomic number

proton number same as atomic number

quicklime calcium oxide

radioactive having an unstable nucleus that will emit particles and waves to achieve a more stable nucleus

range a number of things that are all of the same general type, or the extent of a variable or series

rate the speed at which the amount of reactants decreases or the amount of products increases. It is measured as a change in the concentration (or amount) of reactants or products per unit time

reactivity series a list of elements (mainly metals) in order of decreasing reactivity

redox reduction and oxidation. A redox reaction involves both reduction and oxidation occurring together

reducing agent something that reduces something else by giving electrons to it. A reducing agent is oxidised in a chemical reaction

reduction loss of oxygen or gain of electrons

refinery gases a mixture of methane, ethane, propane and butane. This mixture is commonly used as liquefied petroleum gas (LPG) for domestic heating and cooking

relative atomic mass the weighted average mass of the isotopes of the element, relative to the mass of 1/12th of a ^{12}C atom

relative formula mass the weighted average mass of a formula unit of a compound, relative to the mass of 1/12th of a ^{12}C atom. It is sometimes called relative molecular mass, when it refers to covalent molecules

repeat unit the basic unit which repeats itself in a chain to form a polymer

residue the solid left on the filter paper during filtration

reversible a reversible reaction is one that can go both ways, in other words, reactants react to form products and products can react to form reactants

R_f value the retardation factor, which is calculated as the distance moved by a spot (from the pencil line) divided by the distance moved by the solvent front (from the pencil line) on a chromatogram

rust the corrosion of iron in the presence of water and oxygen. The rust formed has the formula $Fe_2O_3 \cdot xH_2O$, where x is a variable number, and can be called hydrated iron(III) oxide

sacrificial protection a method of preventing rusting by attaching a block of a more reactive metal to iron. The more reactive metals undergo oxidation in preference to the iron

salt a compound formed when a hydrogen is replaced by a metal or ammonium in an acid

saturated compound a compound containing only carbon–carbon single bonds with no carbon–carbon double or triple bonds

saturated solution a solution that contains as much dissolved solid as possible at a particular temperature

scale up make larger

scrubbing removing pollutant gases from the gases produced in a combustion reaction

set-up the way that something is organised or arranged. This can refer particularly to chemical apparatus

shells a series of levels where electrons are found outside the nucleus. Also called energy levels. Each shell can hold a certain number of electrons

simple distillation a process used to separate two liquids of different boiling points, or to separate the solvent and solid solute from a solution

slaked lime calcium hydroxide

soak make very wet

solubility the mass of solute which must dissolve in 100 g of solvent to form a saturated solution at a particular temperature

solute the substance that dissolves in a solvent

solution the mixture formed when a solute dissolves in a solvent

solvent the liquid that a solute dissolves in

soot black powder consisting largely of carbon

spark very small pieces of burning material produced in a fire or by hitting and rubbing two hard objects together that leads to a sudden discharge of light

specific heat capacity the amount of heat needed to raise the temperature of 1 g of a substance by 1 °C

spectator ion an ion that is not changed in a chemical reaction. It is omitted from both the reactant and the product sides when writing ionic equations

spitting sending out small pieces of something, for example from a fire

stability a term used to describe the relative energies of the reactants and the products in a chemical reaction. The more energy a chemical has, the less stable it is.

straight chain a molecule with no branches in its molecular structure

structural formula a formula that shows how the atoms are joined together in a molecule. It is often written in a condensed form by omitting all the carbon–carbon and carbon–hydrogen single bonds

structural isomerism the existence of two or more different structures with the same molecular formula

structural isomers molecules with the same molecular formula, but different structural formulae

sublimation the change of state from a solid to a gas

subscript a number or symbol written below the line

substitution a chemical reaction in which an atom or group of atoms in a molecule is replaced by a different atom or group of atoms. For example, when alkanes react with halogens in the presence of ultraviolet light, the hydrogen atoms in the alkanes are replaced by halogen atoms

successful collisions collisions with energy greater than or equal to the activation energy. These collisions result in reactions

tangent a straight line that touches a curve, but does not cut across it

tarnish become dull and lose colour

thermal decomposition decomposition reaction that requires heating to occur

trace a very small quantity

trickle flow slowly in drops or in a thin stream

triple bond atoms sharing three pairs of electrons in a covalent bond

ultraviolet radiation (UV light) the part of the electromagnetic radiation spectrum that has wavelengths between those of visible light and X-rays. It is invisible to the human eye

undergo experience something

unsaturated compounds that contain one or more carbon–carbon double or triple bonds

vapours gases that are produced when a liquid is heated

vinegar a dilute solution of ethanoic acid in water

viscous a liquid that is resistant to flow

volatile a substance that evaporates easily

water of crystallisation water molecules that are part of a crystal structure in which they are chemically bound up with a salt. They are represented by $\cdot nH_2O$ in the formulae of compounds, for example $CuSO_4 \cdot 5H_2O$ means there are five water molecules associated with each $CuSO_4$ unit

weighted average an average which takes into account the percentage abundance of the components

wick the piece of thread/string in a candle, or alcohol burner, from which the flame comes when you light it

word equation a representation of a chemical reaction using the names of the chemicals only

yeast a group of single-cell fungi that contain enzymes to convert sugar into ethanol

yield the amount of something that is produced in a chemical reaction

PHYSICS GLOSSARY

absorption absorption is the opposite of reflection: soft foam surfaces absorb sound, matt black surfaces absorb light and heat

accelerating getting faster, increasing velocity

acceleration the rate of increasing velocity

alternating voltage a voltage that is continuously changing in value and direction

amplitude the maximum distance moved by a vibrating object from its equilibrium position

angle of incidence angle between the incoming ray and the normal

angle of reflection angle between the reflected ray and the normal

angle of refraction angle between the refracted ray and the normal

apparatus equipment used in investigations and experiments

applications uses

asteroids small rocky objects orbiting the Sun, mostly found between the orbits of Mars and Jupiter.

atoms small particles from which everything is made

attract pull together

bacteria single-celled organisms, some types of which cause illness

calories unit of energy no longer used except in measuring the amount of energy in food

cells sources of electrical energy

circuits in electricity and electronics, complete conducting paths for electricity; circuit is sometimes used as a term for electronic apparatus

collision two or more moving objects hitting each other

comet object often made of ice and rocks that orbits the Sun in an elongated orbit

compressed squeezed into a very small space

compression squashing together

conduction thermal conduction: the movement of heat through a solid; electrical conduction: the movement of electric charge through matter

conductor a material that allows electricity to flow through it easily

control rods rods used in a nuclear reactor to slow down or stop a nuclear chain reaction

convection the movement of heat in a fluid (that is, a gas or liquid) as the fluid expands and rises when warmed

core the centre of something as in, for example, the Earth's core

deceleration getting slower, decreasing velocity

diameter the width of a circle, cylinder or sphere

dimmer switch a device used to alter the brightness of a bulb or light

displacement the distance a particle has moved from its equilibrium (undisturbed) position

dissolves broken down into tiny particles or molecules by the action of a liquid, for example, sugar dissolving in water

Doppler effect the change in frequency (and wavelength) caused by the relative movement of the source of the waves or the observer

drag coefficient a measure of how easily an object can move through a fluid (liquid or gas)

electrode a metal plate or rod by which electricity can enter or leave an electrical device

electromagnetic spectrum family of waves including radio waves, microwaves, infrared waves, visible light, ultraviolet and x-rays

elements in chemistry: pure substances made up of only one type of atom; in general use: part of something

emission something emitted from a system

emitted given out

evaporate change from a liquid into a gas (usually at a temperature lower than the boiling point of the liquid)

exerted acted on

filament coil of wire in a bulb that glows when electricity passes through it

fission the breaking up of an atom into smaller parts

flex wire

force a push or a pull

fossil fuels substances used to provide energy when burned that have formed over millions of years from dead animal or vegetable matter

fraction a part of; sometimes represented mathematically as a ratio of a smaller number over a larger number, for example, ½ for a half

frequency the number of waves or vibrations made each second

friction a force between two solid surfaces trying to move across each other that tries to stop movement happening

fusion reaction when the centres of atoms (nuclei) join together

generator a device that transfers mechanical energy to electrical energy – that is, a source of electrical energy

glows emits light

gradient the slope of a line or surface

gravitational field strength how great the effect of gravity acting on an object is, usually given as force per unit mass

gravity the force that objects with mass exert on each other

half-life the length of time it takes for the activity of an amount of a radioactive substance to halve

halogen light bulb a light bulb that contains a small amount of a halogen such as iodine or bromine

heating elements coils of wires used to transfer electrical energy to heat energy

hemisphere half a sphere, as in the northern hemisphere referring to the part of the Earth above the equator

hydroelectric power electrical energy produced from the energy in water stored high above ground level in mountain lakes and reservoirs

induced created, caused, produced

insulator a material through which it is very difficult or impossible for electricity to flow

inversely proportional something varying such that it decreases by equal amounts as some other factor increases by equal amounts

kinetic energy the type of energy that a moving object stores

light emitting diodes (LEDs) a material that gives off light when current passes through it

light gates electronic systems that are used to switch something on or off, like a digital clock when a light beam between a light source and a detector is broken

longitudinal wave the vibrations of these waves are along the direction in which the wave travels

magnetic field a place where we can detect magnetism

magnification how many times bigger, for example, a magnification of two indicates it is twice as big

mass the amount of matter in an object; that property of an object that determines how easy it is to speed up or slow down

metric related to a system of units of measurement based on kilograms, metres and second, for example, SI units are metric

moderator a material used in nuclear reactors to make neutrons move more slowly

molecules groups of atoms joined together

negatively charged has more negative charges than positive charges

non-porous a material that does not allow liquids to pass through it

normal (the) a line at 90 degrees to the surface

nuclear to do with the nucleus of an atom, for example, the forces that hold neutrons and protons tightly together in the nucleus is a nuclear force

orbit the path of a planet around a star or a satellite around a planet

orbital speeds the speeds of objects as they circle other objects, for example, the Moon going around the Earth

ore many chemical elements are bound up with other elements in rocks; these rocks are called ores

oscilloscope a device used to observe waves and vibrations

ozone layer a layer high above the Earth's surface that contains lots of ozone (O_3)

parabola a particular shape of curved surface used to focus light, heat, radio waves, and so on, to a particular point

parallax error not reading a scale on a ruler or other measuring instrument by looking at the scale straight on (at right angles to the scale)

penetrating power the measure of the ability of a wave to travel through objects

perpendicular upright or at right-angles (90 degrees to something)

phenomena events, occurrences

photosynthesis the process in green plants that uses light from the Sun to produce energy for the plant to grow

photovoltaic cells devices that transfer energy from light (typically the Sun) into electrical energy; used in renewable energy projects; not to be confused with solar heat exchangers that transfer heat from the Sun to water, allowing energy to be stored in tanks of heated water

pitch (of a sound) the interpretation of the frequency of a sound by a person's brain/ear

pivot the point around which something can turn or rotate

plugs and sockets the most common way to obtain electrical energy from the mains supply

prisms transparent, triangular shaped pieces of glass or plastic

proportional something varying such that it increases by equal amounts as some other factor increases by equal amounts

quartered decreased by a factor of 4, that is, ¼ of the original

radioactive having an unstable nucleus that will emit particles and waves to achieve a more stable nucleus

radioisotope isotope of an element that has the same number of protons in the nucleus but different numbers of neutrons; a radioisotope is unstable, radioactive; also called radioactive isotope

ratio a way of comparing the quantities of things, for example, a ratio of 3:1 means there is three times the amount of one thing compared to the other

reaction the response to an action; in physics, reaction is the equal force that acts as a result of an action force, equal in size but opposite in direction

rectifier circuits circuits used to change alternating currents into direct currents

red-shift emitted waves have their wavelength increased, that is, moved to the red end of the spectrum

refractive index a measure of the change in speed a wave experiences when it travels across the boundary between two media, e.g. air and glass; the index also describes how much the direction of the wave changes; $n = \sin i / \sin r$

relative charge the charge compared with the charge on an electron

repel push away

resistance the difficulty current experiences in a circuit

resultant force the total effect of two or more forces acting on an object; sometimes referred to as an unbalanced force

rotate to turn or spin about an axis (central point)

rotating turning

scanned looked at over an area, as in scanning pages from a book in a photocopier

solenoid a long coil

sonar method of using sound waves to detect objects and measure their distance

spiral galaxy a very large group of stars that forms a spring-like winding shape

squared in maths, something multiplied by itself

sterilised made free of dirt and bacteria

sterilise remove all bacteria and germs

stroboscope apparatus that produces short bright flashes of light at regular intervals (that is at a known frequency, flashes per second); the apparatus allows the frequency to be varied; used to allow a series of images of a moving object to be captured photographically or to determine the speed of rotating objects

subtract take away from

sum the result of adding things together

terminal velocity the maximum speed that a moving object is able to reach

thermal relating to heat; also used to describe upward air currents called convection

thermistor a conductor whose resistance changes a lot when its temperature changes

thrust a type of pushing force, like the thrust of rocket motors

time period time needed to make one complete wave or vibration

tracers the use of substances that can be detected to show the movement of liquids through a person's body or pipes in machinery

transverse wave the vibrations of this wave are at right angles to the direction in which the wave is moving

trebled increased by a factor of 3, that is, 3 × the original

tuning fork a steel instrument that when it vibrates produces sound waves of a constant frequency and wavelength

unbalanced force non-zero resultant force

unstable likely to change; referring to an object it means to tip over; in the case of a radioactive isotope it means to emit particles that change the make-up of a nucleus

upthrust an upward force acting on something; an object in a liquid or gas will have an upward force acting on it called the buoyant (to do with floating) upthrust

vacuum containing no matter at all; the space between stars is a nearly perfect vacuum; a vacuum flask has a gap around the inner container that is completely emptied of any matter

vertical upwards, at right angles to the ground

vibrate move continuously back and forth

visible light waves that can be detected by the eye

voltage amount of energy transferred to each coulomb of charge that passes

wavelength the distance from one point on a wave to the same point on the next wave

waves vibrations which carry or move energy

weight the force of gravity acting on a body

weightless the condition in which a body does not experience the force we call weight; if you stand on weighing scale in a lift that is accelerating toward the Earth at 10 m/s^2 the scales will show that you weigh nothing – this is just one way in which weightlessness can happen

BIOLOGY

UNIT 1 ANSWERS

CHAPTER 1

1 ▶ B **2 ▶** A **3 ▶** A

4 ▶ a Diagram should show each part of a plant cell and its function, e.g. cell wall (maintains shape of cell), cell membrane (controls entry and exit of substances), cytoplasm (where metabolism/reactions take place), vacuole (stores dissolved substances), nucleus (controls activities of cell), chloroplasts (photosynthesis), mitochondria (respiration).

b An animal cell lacks a cell wall, a large permanent vacuole and chloroplasts.

5 ▶ Description, in words or diagrams, should include the following points:

- enzymes are biological catalysts
- they speed up reactions in cells without being used up
- each enzyme catalyses a different reaction
- the production of enzymes is controlled by genes
- enzymes are made of protein
- the substrate attaches to the enzyme at the active site
- the substrate fits into the active site like a key in a lock
- this allows the products to be formed more easily
- intracellular enzymes catalyse reactions inside cells
- extracellular enzymes are secreted out of cells (e.g. digestive enzymes)
- they are affected by changes in pH and temperature.

6 ▶ a About 75 °C.

b At 60 °C the molecules of enzyme and substrate have more kinetic energy and move around more quickly. There are more frequent collisions between enzyme and substrate molecules, so more reactions are likely to take place.

c The microorganism lives at high temperatures, so it needs 'heat-resistant' enzymes with a high optimum temperature.

d It is denatured.

7 ▶ Diffusion is the net movement of particles (molecules or ions) from a high to low concentration. It does not need energy from respiration. Active transport uses energy from respiration to transport particles against a concentration gradient.

8 ▶ a They carry out most of the reactions of respiration in the cell, providing it with energy.

b Active transport. This uses the energy from the mitochondria.

c Diffusion. The removal of glucose at A lowers the concentration inside the cell, so that the concentration at B is higher than inside the cell. Therefore glucose can diffuse down a concentration gradient.

d Increases the surface area for greater absorption.

CHAPTER 2

1 ▶ D **2 ▶** A **3 ▶** B **4 ▶** C

5 ▶ a i Fungi **ii** Protoctists **iii** Plants **iv** Bacteria

b Like most protoctists, *Euglena* is a microscopic, single-celled organism. It has features of both plant and animal cells: like plants, it contains chloroplasts; like animals, it can move.

6 ▶ a Diagram should show a core of DNA or RNA surrounded by a protein coat. (It may also have an outer envelope or membrane derived from the host cell.)

b A virus can be considered either as living or as a chemical. It does not have any of the normal characteristics of living things, except that it is able to reproduce.

c Viruses can reproduce only inside a host cell, by taking over the cell's genetic machinery to make more virus particles. So viruses are all parasites.

7 ▶ a An animal that does not have a vertebral column (backbone).

b Fine, thread-like filaments forming the feeding network of cells of a fungus.

c A type of nutrition used by most fungi and some bacteria, where the organism feeds on dead organic material by digesting it using extracellular enzymes.

END OF UNIT 1 QUESTIONS

1 ▶ a i nucleus, mitochondrion (both needed for 1)

ii nucleus, chloroplast, mitochondrion (all needed for 1)

iii nucleus, mitochondrion (both needed for 1).

b The cells in a root have no chloroplasts because they don't receive any light and so can't carry out photosynthesis (1).

c Nucleus controls the activities of the cell (1); chloroplast absorbs light energy for photosynthesis (1); mitochondrion carries out some reactions of respiration to release energy (1).

2 ▶ a The artery is an organ because it is made of several tissues (1); the capillary is made up of only one type of cell (1).

b i Two from: Breaks down large insoluble molecules (1) into smaller soluble molecules (1) that can be absorbed (1)

ii (1 mark for organ, 1 mark for function).

Three from:

- mouth: chews / breaks down food into smaller pieces / produces saliva
- oesophagus (gullet): moves food from mouth to stomach
- stomach: produces digestive enzymes
- pancreas: produces digestive enzymes
- liver: makes bile

- ileum (small intestine): produces digestive enzymes / absorbs products of digestion
- colon (large intestine): absorbs excess water
- rectum: stores waste (faeces).

iii (1 mark for system, 2 marks for organs).
Two from:

- breathing system: trachea, lung, diaphragm
- circulatory system: artery, vein, heart
- musculoskeletal system: muscle, joint, (named) bone
- nervous system: brain, spinal cord
- reproductive system: testis, ovary, uterus, penis
- excretory system: kidney, bladder.

3 ▶ a i 4 g (1). Mass at start was 100 g, decreased to 96 g due to oxygen lost (1).

ii Half this mass = 2 g (1). This loss in mass occurs by (approximately) 0.5 minutes / 30 seconds (1).

iii At the start there are a lot of enzyme and substrate molecules, so there are a lot of successful collisions (1). As the reaction proceeds, the number of substrate molecules decreases, so there are fewer successful collisions (1).

b i There would be no difference / 4 g formed (1); because the temperature affects only the reaction rate, not the end point (1).

ii The time would be shorter (1) because the rate of reaction is speeded up by the increase in temperature (1).

4 ▶ a 1 mark for each correct row in the table.

Feature	Active transport	Osmosis	Diffusion
particles must have kinetic energy	✗	✓	✓
requires energy from respiration	✓	✗	✗
particles move down a concentration gradient	✗	✓	✓

b i (As the temperature rises) ions gain kinetic energy (1), so they move faster (1).

ii Above this temperature the cell membranes are being denatured (1) so are more permeable to ions (1).

5 ▶ a i So that each of the two cells produced (1) will have the correct number of chromosomes / correct amount of DNA after the division (1).

ii The nucleus has divided into two (1).

b i They increase the surface area for absorption (1).

ii They (further) increase the surface area for absorption (1).

iii As the glucose moves out of the cell, the concentration inside the cell decreases (1) and increases the concentration gradient for diffusion of glucose into the cell (1).

6 ▶ a $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (1 for each correct part)

b It is the same (1), because there are six molecules of each / same number of molecules / same number of moles (1), 1 mole of any gas has the same volume (1).

c Any sensible experimental error stated (1) with brief explanation (1).

d No oxygen would be used up (1), so distance moved would be less / bead would not move (1).

7 ▶ (1 mark for each correct row)

Feature	Type of organism		
	Plant	Fungus	Virus
they are all parasites	✗	✗	✓
they are made up of a mycelium of hyphae	✗	✓	✗
they can only reproduce inside living cells	✗	✗	✓
they feed by extracellular digestion by enzymes	✗	✓	✗
they store carbohydrate as starch	✓	✗	✗

8 ▶ (One mark for each correct underlined term)
Plants have cell walls made of cellulose. They store carbohydrate as the insoluble compound called starch or sometimes as the sugar sucrose. Plants make these substances as a result of the process called photosynthesis. Animals, on the other hand, store carbohydrate as the compound glycogen. Both animals' and plants' cells have nuclei, but the cells of bacteria lack a true nucleus, having their DNA in a circular chromosome. They sometimes also contain small rings of DNA called plasmids, which are used in genetic engineering. Bacteria and fungi break down organic matter in the soil. They are known as decomposers / saprotrophs. Some bacteria are pathogens, which means that they cause disease.

9 ▶ a Germinating seeds produce heat (1) from respiration (1).

b To kill bacteria on the seeds (1)

c To allow oxygen into the flask (1)

d Mass of seeds / number of seeds / age of seeds (1)

10 ▶ Any six for 6 marks, from:

- Use solution of ATP, compare with (control using) water (1)
- Same type of meat fibres / named type (1)
- Several replicates / number of replicates suggested, e.g. 10 (1)
- Measure length before treatment (1)
- Measure length after treatment / change in length / % change (1)
- Other controlled variables: temperature / volume of solutions / starting length (max. 2)

UNIT 2 ANSWERS

CHAPTER 3

1 ▶ C **2 ▶** A **3 ▶** B **4 ▶** B

5 ▶

	Action during inhalation	Action during exhalation
external intercostal muscles	(contract)	relax
internal intercostal muscles	relax	contract
ribs	move up and out	(move down and in)
diaphragm	contracts and flattens	relaxes and becomes dome-shaped
volume of thorax	increases	decreases
pressure in thorax	decreases	increases
volume of air in lungs	increases	decreases

6 ▶ When we breathe in, the external intercostal muscles between our ribs contract, pulling the ribs up and out. The diaphragm muscles contract, flattening the diaphragm. This increases the volume in the chest cavity (or thorax), lowering the pressure there, and causing air to enter from outside the body, through the nose or mouth. This is called ventilation. In the air sacs (or alveoli) of the lungs, oxygen enters the blood. The blood then takes the oxygen around the body, where it is used by the cells. The blood returns to the lungs, where carbon dioxide leaves the blood and enters the alveoli. When we breathe out, the external intercostal muscles relax and the ribs move down and in. The diaphragm muscles relax, and the diaphragm returns to a dome shape. These changes decrease the volume of the chest cavity, increasing the pressure in the thorax, pushing the air out of the lungs.

7 ▶ a When the volume of the chest is increased by the movements of the ribs and diaphragm, the drop in pressure in the chest cavity draws air into the pleural cavity through the puncture in the chest wall, instead of through the mouth or nose into the lung.

b Each lung is isolated from the other by being in a separate pleural cavity, so a pneumothorax on one side will not affect the opposite lung.

c A tube is inserted through the chest wall into the pleural cavity on the side of the injured lung. This stops ventilation in that lung, while the other lung is ventilated normally.

8 ▶ a The rings support the trachea so that it does not collapse during inhalation.

The gap in the 'C' allows food to pass down the oesophagus, which runs next to the trachea, without catching on the rings.

b The short distance allows easy diffusion of oxygen into the blood, and diffusion of carbon dioxide out of the blood.

c The mucus traps bacteria and dirt particles. The cilia beat backwards and forwards to sweep these towards the mouth, preventing them entering the lungs.

d Smoke contains carbon monoxide, which displaces oxygen from the haemoglobin of the red blood cells of the smoker.

e The addictive drug in tobacco smoke is nicotine. Smokers who are trying to give up can use patches or gum to provide the nicotine they normally get from cigarettes, reducing the craving to smoke.

f The large surface area is provided by the alveoli. It allows for efficient diffusion of oxygen into the large blood supply, and efficient removal of the waste product, carbon dioxide.

9 ▶ Bronchitis is a lung disease caused by irritation of the linings of the airways to the lungs. It may be made worse by bacteria infecting the bronchial system.

Emphysema is a lung disease where the walls of the alveoli break down and then fuse together, reducing their surface area. (Both diseases may be caused by smoking.)

10 ▶ a Some points are:

- non-smokers have a low death rate from lung cancer at all ages
- the death rate from lung cancer among smokers increases with age
- the death rate increases with the number of cigarettes smoked per day.

(Numbers should be used from the graph to illustrate any of these points.)

b For 55-year-olds smoking 25 a day: about 4.5 per 1000 men (or 45 per 10000 men)

For 55-year-olds smoking 10 a day: less than 1 per 1000 men

c Probably this investigation. The graph shows a direct relationship between number of cigarettes smoked and incidence of lung cancer, in one particular type of person (middle-aged male doctors): in other words, a more controlled group. In Table 3.2 the patients were matched for age, sex etc. but were from a more varied background. There could be other reasons for the correlation that had not been considered. However, they both show a strong link.

11 ▶ The leaflet should not be too complicated or have too much information so that it puts the reader off. It must have a clear message.

CHAPTER 4

1 ▶ D **2 ▶** A **3 ▶** D **4 ▶** B

5 ▶ a Starch: Take a sample of the water in a spotting tile and add a drop of iodine solution. If starch is present, the colour will change from orange to blue-black.

Glucose: Take a sample of the water in a test tube and add blue Benedict's solution. Place the tube in a water

bath and heat until it boils. If glucose is present, a brick-red precipitate will form.

b The starch molecules are too large to pass through the holes in the Visking tubing. Glucose molecules are smaller, so they can pass through.

c The blood

d Large, insoluble food molecules are broken down into small, soluble ones.

6 ▶ a It is body temperature.

b It had been broken down into smaller molecules called peptides (short chains of amino acids) forming the clear solution.

c The enzyme pepsin does not work in alkaline conditions: it is denatured.

d The experiment is looking at the effects of pepsin on the egg white. The Control is carried out without the enzyme; all other factors are the same. This shows that it is the enzyme that breaks down the protein. In other words, the egg white does not break down by itself.

e The enzyme works more slowly at a lower temperature. There are fewer collisions between enzyme and substrate molecules, because they have less kinetic energy.

f Hydrochloric acid kills bacteria in the food entering the stomach.

g By alkaline secretions in the bile and pancreatic juice.

7 ▶

Enzyme	Food on which it acts	Products
(amylase)	starch	maltose
(trypsin)	protein	peptides
lipase	fats	(fatty acids and glycerol)

8 ▶ Descriptions of any four of the following:

- length, which increases time and surface area for absorption
- folds in lining, which increase surface area
- villi covering lining, which increase surface area
- microvilli on lining cells, which increase surface area
- capillary networks in villi, where products are absorbed
- lacteals in villi, which absorb fats.

9 ▶ The account should include full descriptions of most of the following points:

- digestion of starch to maltose in the mouth, action of saliva in moistening food
- mechanical digestion by the teeth
- movement through the gut by peristalsis (diagram useful)
- digestion of protein by pepsin in the stomach and the role of hydrochloric acid
- emulsifying action of bile from the liver on fats
- pancreatic enzymes (amylase, trypsin, lipase) and their role in digestion of starch, protein and fats
- adaptations of the ileum for the absorption of digested food (see question 8)
- role of the colon in absorption of water.

CHAPTER 5

1 ▶ B **2 ▶** C **3 ▶** A **4 ▶** B

5 ▶ a Single: fish; double: human or other named mammal.

b i (Either) The blood passes once through the heart in a single system, and twice through the heart in a double system for every complete circulation of the body.

(Or) In a double system the blood flows from the heart through one circuit to the lungs, then back to the heart and out through another circuit to the rest of the body.

ii A double circulatory system pumps the blood twice per circulation so higher pressures can be maintained.

c Diffusion can take place because a single-celled organism has a large surface area compared with its volume and the distances for substances to move inside the cell are short.

6 ▶ a A red blood cell has a large surface area compared with its volume; contains haemoglobin; and has no nucleus, so more space is available for haemoglobin.

b i Oxygen dissolves in the liquid lining the alveoli and then diffuses down a concentration gradient through the walls of the alveoli and capillaries into the plasma and into the red blood cells.

ii Oxygen dissolves in the plasma and then diffuses down a concentration gradient through the walls of the capillaries into the muscle cells.

c Dissolved in plasma

7 ▶ a Arteries have thick walls containing much muscle tissue and elastic fibres. These adaptations allow their walls to stretch and recoil under pressure.

b Veins have valves, thin walls with little muscle, and a large lumen; arteries have no valves (except at the start of the aorta and pulmonary artery), thick muscular walls with many elastic fibres, and a narrow lumen.

c Capillaries have thin walls / walls one cell thick, to allow exchange of materials. They have a very small diameter to fit between other cells of the body.

8 ▶ a A = left atrium, B = (atrioventricular) valves, C = left ventricle, D = aorta, E = right atrium

b To ensure blood keeps flowing in one direction / prevent backflow of blood

c i A **ii** E

9 ▶ a i A (red blood cell), identified by its colour (red) and biconcave disc shape

ii B (lymphocyte), identified by its colour (white) and large nucleus (to produce antibodies quickly)

iii C (phagocyte), identified by its colour (white), variable shape (shows it is flowing) and lobed nucleus

b Platelets – blood clotting

10 ▶ a C: heart rate is increasing so more blood can be pumped to muscles

b E: brief jump in heart rate

c A: lowest rate

d B: increases from minimum to steady

11 ▶ a i Low rate (75 beats/minute) because body is at rest, need for oxygen is low

ii Rate increases because more blood carrying oxygen for respiration needs to be pumped to muscles

iii Rate decreases as need for oxygen is reduced / lactate produced during exercise is removed (repaying oxygen debt)

b The shorter the recovery period, the fitter the person

CHAPTER 6

1 ▶ D **2 ▶** B
3 ▶ C **4 ▶** D

5 ▶ a Changes that take place in the shape of the lens to allow the eye to focus upon objects at different distances.

b The replacement artificial lens cannot change shape.

c The ciliary muscles contract and the suspensory ligaments slacken. The shape of the lens becomes more convex, refracting the light more.

6 ▶ a

Function	Letter
refracts light rays	G
converts light into nerve impulses	A
contains pigment to stop internal reflection	B
contracts to change the shape of the lens	E
takes nerve impulses to the brain	D

b i H

ii Contraction of circular muscles in the iris reduces the size of the pupil, letting less light into the eye. Contraction of radial muscles increases the size of the pupil, letting more light into the eye.

iii To protect the eye from damage by bright light, and to allow vision in different light intensities.

7 ▶ a i Sensory neurone

ii Relay neurone

iii Motor neurone

b The sensory neurone carries impulses from sensory receptors towards the central nervous system. The motor neurone carries impulses out from the CNS to effector organs (muscles and glands). The relay neurone links the other two types of neurone in the CNS.

c X: white matter, Y: grey matter, Z: dorsal root ganglion

d Electrical impulses

e The gap between one neurone and another is called a synapse. An impulse arrives at the end of an axon and causes the release of a chemical called a neurotransmitter into the synapse. The neurotransmitter diffuses across the synapse and attaches to the membrane of the next neurone. This starts an impulse in the second nerve cell.

f Many drugs imitate or block a neurotransmitter; therefore, they can stop the pain impulse from passing across the synapse.

8 ▶ a P: cell body, Q: dendrite, R: axon

b $\text{Speed} = \frac{\text{distance}}{\text{time}}$

$= \frac{1.2\,\text{m}}{0.016\,\text{s}}$

$= 75\,\text{m/s}$

c Insulation / prevents short circuits with other actions. (Also speeds up conduction).

d Person would not be able to control their muscle contractions / would not be able to coordinate body movements / 'wrong' muscles would contract

9 ▶ a A wide variety of answers are possible, such as:

- dust in the eye – secretion of tears
- smell of food – secretion of saliva
- touching a pin – withdrawal of hand
- attack by a predator – increased heart rate
- object thrown at head – ducking.

b Nature and role of receptor and effector correctly explained, e.g. for 'dust in the eye' above:

i The receptors consist of touch receptors in the eye. They respond by generating nerve impulses (which eventually stimulate the tear glands).

ii Tear glands are the effectors. They secrete tears, washing the irritant dust out of the eyes.

c Chain of events correctly described, e.g. for 'dust in the eye' above:

Dust enters the eye and stimulates a touch receptor in the surface of the eye. The receptor sends nerve impulses along sensory neurones to the CNS (brain). In the CNS, impulses pass from sensory neurones to motor neurones via relay neurones. Impulses pass out from the CNS to the tear glands via motor neurones. These impulses stimulate the tear glands to secrete tears.

CHAPTER 7

1 ▶ B **2 ▶** B **3 ▶** C

4 ▶ a 'Hormones' are chemical messenger substances, carried in the blood. 'Secreted' refers to the process where a cell makes a chemical that passes to the outside of the cell. 'Glands' are organs that secrete chemicals, and 'endocrine' glands secrete their products into the blood.

b A = insulin, B = adrenaline, C = testosterone, D = progesterone

5 ▶ a Glucose has been absorbed into the blood following a meal (lunch!).

b The high concentration of glucose in the blood is detected by the pancreas, which secretes the hormone insulin into the blood. Insulin stimulates the uptake of blood glucose into the liver, where it is converted into an insoluble storage carbohydrate called glycogen.

c i Untreated diabetes leads to weakness and loss of weight, and eventually coma and death.

ii Coloured test strips to detect glucose in the urine, and direct measurement of blood glucose using a sensor

iii Reducing the amount of carbohydrate in the diet, and injections of insulin

CHAPTER 8

1 ▶ D **2 ▶** C

3 ▶

Changes taking place	Hot environment	Cold environment
(sweating)	increased sweat production so that evaporation of more sweat removes more heat from the skin	decreased sweat production so that evaporation of less sweat removes less heat from the skin
(blood flow through capillary loops)	vasodilation increases blood flow through surface capillaries so that more heat is radiated from the skin	(vasoconstriction decreases blood flow through surface capillaries so that less heat is radiated from the skin)
(hairs in skin)	hairs lie flat due to relaxed muscles, trapping less air next to the skin	hairs are pulled erect by muscles, trapping a layer of insulating air next to the skin
(shivering)	no shivering occurs	shivering occurs; respiration in muscles generates heat
(metabolism)	metabolism slows down, e.g. in organs such as the liver, reducing heat production	metabolism speeds up, e.g. in organs such as the liver, generating heat

4 ▶ a The average body temperatures of birds is slightly higher than that of mammals. This is because they have a higher metabolic rate, needed for flight (note that the flightless birds have a lower body temperature).

b No. For example, the temperatures of the camel and the polar bear are the same, despite their different habitats.

c The fur traps air, providing insulation. The colour acts as camouflage (so they are not so easily seen by prey).

CHAPTER 9

1 ▶ C **2 ▶** D **3 ▶** D **4 ▶** C

5 ▶ a A = placenta, B = umbilical cord, C = amnion, D = amniotic fluid, E = uterus (womb), F = cervix

b The function of the placenta is the transfer of oxygen and nutrients from the mother's blood to the blood of the embryo / fetus, and the removal of waste products such as carbon dioxide and urea from the fetus to the mother.

c Just before birth, contractions of the muscle of the uterus (E) cause the amnion to rupture, allowing the amniotic fluid (D) to escape. This is the 'breaking of the waters'.

d During birth, the cervix (F) becomes fully dilated, and strong contractions of the muscles of the uterus (E) push the baby out.

6 ▶ a Method B: the formation of a new individual (the bud) does not involve sex cells from sex organs (as shown in method A).

b In asexual reproduction, all the cells of the new individual are produced by mitosis from one cell in the parent. When cells divide by mitosis, all the new cells are genetically identical to the parent cell, and to each other.

c If *Hydra* is well adapted to its environment, and the environment is stable, asexual reproduction will produce offspring that are also well adapted. However, if the environment changes, the offspring may not be well adapted and may die out. Sexual reproduction produces offspring that show variation, so some of the new *Hydra* may be better adapted to survive in the new conditions.

7 ▶ a i A **ii** B **iii** D **iv** A

b i oestrogen

ii Approximately 29–30 days. This can be seen by counting the days from the start of the first menstruation (day 0) to the start of the next menstruation.

iii Fertilisation is most likely to have taken place about 15 days after the day when the last menstruation started. The last menstruation started on about day 57, so fertilisation probably took place on about day 72. (Note – this is very approximate!) After day 72 there is no menstruation, so the uterus lining becomes thicker.

iv To prepare for implantation of the fertilised egg.

8 ▶ There is evidence for and against the involvement of pollutants in lowering the sperm count, and indeed whether or not the count has become lower at all. A good account of the student's findings should be a balanced one, giving both sides of the argument. It should be illustrated with some graphs or tables of data.

9 ▶ a A = oestrogen, B = progesterone

b corpus luteum

c To prepare for the implantation of a fertilised embryo

d 13

e Progesterone maintains the thickened uterus lining and prevents menstruation, as well as preventing further ovulation by inhibiting release of FSH and LH.

i Progesterone is secreted by the corpus luteum.

ii Progesterone is secreted by the placenta.

END OF UNIT 2 QUESTIONS

1 ▶ a (1 mark for each correct row)

Gas	Inhaled air / %	Exhaled air / %
nitrogen	(78)	(79)
oxygen	21	16
carbon dioxide	0.04	4
other gases (mainly argon)	(1)	(1)

b It increases in exhaled air (1) because carbon dioxide is produced in respiration (1).

c Excretion is getting rid of a waste product of metabolism (1); carbon dioxide is a waste product of respiration (1).

d i Short distance (1) allows rapid / efficient diffusion of oxygen and carbon dioxide (1)

ii Blood brings carbon dioxide and takes away oxygen (1) maintaining a diffusion gradient (1)

iii Increases the surface over which diffusion of oxygen and carbon dioxide can occur (2)

2 ▶ a i A = stomach (1) because it is an acidic pH (1)
B = small intestine (1) because it is an alkaline pH (1)

ii Protein (1)

b i Liver (1)

ii Proteins (1)

iii Proteins (from the urea) are a source of nutrients for the cattle (1).

3 ▶ a A = pulmonary vein, B = aorta, C = right atrium, D = left ventricle, E = renal vein (5)

b X (artery) has narrow lumen / muscular wall (1); Y (vein) has large lumen / little muscle (1)

c i Increases heart rate (1) and volume of blood pumped with each heart beat (1)

ii Two from: increases breathing rate, diverts blood away from intestine to muscles, converts glycogen to glucose in the liver, dilates pupils, causes body hair to stand on end, increases mental awareness, increases rate of metabolism (1 mark for each correct point, maximum 2 marks)

d Reflex action is automatic / involuntary (1), voluntary action is one a person chooses to carry out / is initiated by the brain (1)

e Lactate produced in muscles during exercise needs to be oxidised / removed / oxygen debt needs oxygen (1); oxygen is supplied by increased breathing rate and increased heartbeat (1)

4 ▶ a Labels: cell membrane (1), lobed nucleus (1), cytoplasm (1)

b Two from: has a nucleus (1), irregular shape / not biconcave (1), no haemoglobin (1)

c Two from: ingest / engulf / surround (bacteria) (1), digest / break them down (1), using enzymes (1)

d Three from: lymphocytes (1), make antibodies (1), specific to antigens (1), form memory cells (1)

5 ▶ a All chemical reactions taking place in cells can continue at a steady rate / metabolism doesn't slow down in cold conditions (1)

b i Arterioles: blood remains in core of body and doesn't lose heat (1). Sweat: no heat lost in evaporating the sweat (1). Shivering: increases heat production by respiration (1).

ii They have a lot of muscle fibres in their walls (1).

6 ▶ a i B **ii** C **iii** B **iv** D **v** A (5).

b Pregnancy is most likely to result from sexual intercourse around the time of ovulation (1), i.e. in the middle of the menstrual cycle / around day 14 (1). If a couple avoid having sexual intercourse at this time, the woman is less likely to become pregnant (1).

7 ▶ a B (1). Cell division has reduced the chromosome number (1) from 46 to 23 / to the number present in gametes (1).

b The fertilised egg / zygote has 46 chromosomes (1). It divides by mitosis (1), so that all the cells of the body also have 46 chromosomes (1). In the sex organs, gametes are produced by meiosis (1), which halves the chromosome number to 23 (1). Fertilisation of an egg by a sperm restores the chromosome number to 46 (1).

c Any three for 3 marks, from:

- mitosis involves one division, meiosis involves two
- mitosis forms two cells, meiosis forms four
- mitosis forms cells with the same chromosome number as the parent cell / diploid, meiosis forms cells with half the chromosome number of the parent cell / haploid
- mitosis forms body cells, meiosis forms sex cells / gametes
- mitosis forms cells that are genetically identical, meiosis forms cells showing genetic variation.

8 ▶ Any six for 6 marks, from:

- rats given protein supplement / range of amounts of protein supplement, and rats given no supplement (Control)
- rats same age / same sex / same health / same variety
- several rats in each group (allow 6 or more per group)
- weigh before and after treatment / take other suitable measurement before and after treatment, such as circumference of leg muscles
- suggested time period for treatment (minimum one week)
- calculate (mean) % change in mass
- same diet (apart from supplement)
- same water / same amount of exercise / other suitable controlled factor.

UNIT 3 ANSWERS

CHAPTER 10

1 ▶ A **2 ▶** C **3 ▶** A

4 ▶ **a** Iodine solution, turns from yellow-orange to blue-black.

b Only the green areas that are not covered would contain starch.

c Photosynthesis needs light and chlorophyll. These are only both available in green, uncovered areas.

d A storage carbohydrate. It is insoluble, so can be stored in cells and has no osmotic effects.

5 ▶

Part of leaf	Function	How the part is adapted for its function
palisade mesophyll layer	(main site of photosynthesis)	(cells contain many chloroplasts for photosynthesis)
spongy mesophyll layer	gas exchange surface: uptake of CO_2 and release of O_2 during photosynthesis, some photosynthesis	large surface area to volume ratio; air spaces between cells; many chloroplasts in cells for photosynthesis (but fewer than in palisade layer)
stomata	pores which exchange gases (CO_2, O_2 and water vapour) with the atmosphere	pores formed between two guard cells; guard cells can change shape to open and close pores
xylem	transport of water and minerals	cells consist of dead, hollow vessels, allows transport through the lumen of each vessel; lignified walls for strength, preventing cells collapsing under suction pressure
phloem	transport of products of photosynthesis	sieve tubes with sieve plates forming continuous tubes to transport solutes; cells living, so can exercise control over movement

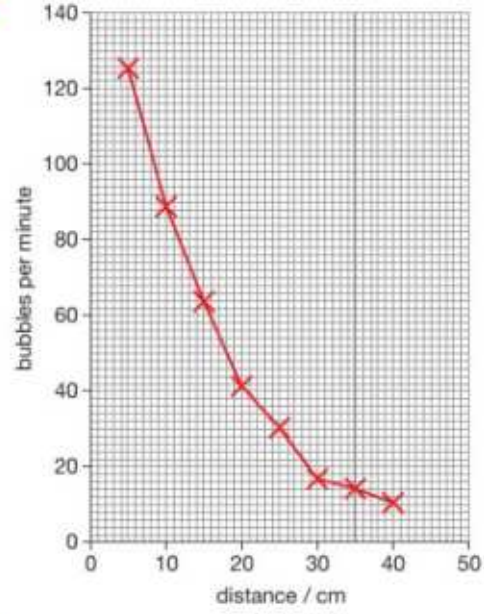
6 ▶

Substance	Use
glucose	oxidised in respiration to give energy
sucrose	main sugar transported in the phloem
starch	storage carbohydrate
cellulose	makes up plant cell walls
protein	growth and repair of cells
lipid	energy store in some plants, e.g. nuts, seeds; part of all cell membranes

7 ▶ **a** The aeration tube supplies oxygen to allow the roots to respire. The foil stops light entering the tube, preventing the growth of algae.

b Phosphate

8 ▶ **a**



b About 54 bubbles per minute

c
- The gas is not pure oxygen, although it has a high oxygen content.
- The bubbles may not be all the same size.
- The water in the test tube may have increased in temperature as the lamp was brought nearer to the tube.

9 ▶ The account should include:
- Description of photosynthesis as a chemical reaction where CO_2 and water are combined using light energy trapped by chlorophyll, forming glucose and oxygen
- Equation for the reaction
- Leaf adaptations: details of palisade mesophyll, spongy mesophyll, stomata and epidermis, xylem and phloem (diagram needed)
- Photosynthesis supplies oxygen for respiration in animals and other organisms; it is needed at the start of food chains; how energy is harnessed by plants as the producers, and then passed to consumers (note: these topics are covered fully in Chapter 14)

CHAPTER 11

1 ▶ C **2 ▶** B

3 ▶ a Loss in mass = (8.2 – 8.0) g = 0.2 g

Percentage change = $\frac{-0.2}{8.2} \times 100 = -2.4\%$

b Osmosis **c** Solution A

d Solution C **e** Solution B

f It is permeable to small molecules such as water, but not permeable to large molecules such as sucrose.

4 ▶ a A = epidermis, B = phloem, C = xylem

b C. Xylem carries water up the stem. The dye is likely to be carried in this water.

CHAPTER 12

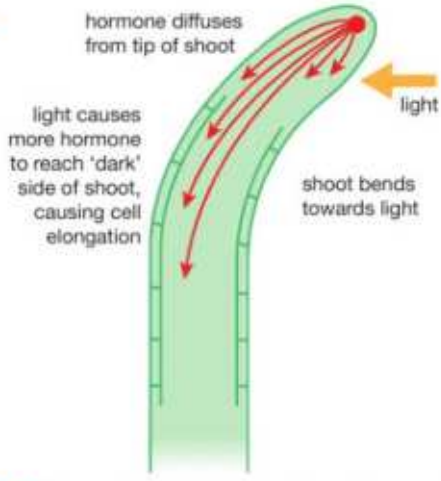
1 ▶ B **2 ▶** B **3 ▶** D **4 ▶** A

5 ▶ a i The direction of light and the direction of gravity

ii The direction of gravity

b The stem grows towards the light, which allows more photosynthesis, and growth of the plant.

6 ▶



7 ▶ a The coleoptile would not bend towards the light. The movement of auxin on the left (dark) side would be interrupted by the mica sheet.

b The coleoptile would grow (bend) towards the source of light. The greater amounts of auxin diffusing down the left side would be unaffected by the placement of the mica sheet. (It might even bend more than a control, with no sheet).

c The coleoptile would grow (bend) towards the source of light. The mica would not interrupt the movement of auxin away from the light.

8 ▶ a Decapitated coleoptiles would produce the least increase in length, because the tip is the source of auxin, which normally stimulates growth. No tip means that there is no auxin, so there will be reduced growth. The tip with the greatest growth is more difficult to predict. The coleoptiles with the tips covered would probably produce the most growth, since auxin is still made by the tip, but none is moved to the left side of the shoot, so there will be no bending, just upward growth.

b Decapitated coleoptiles – no bending, since no auxin produced.

Coleoptiles with tips covered – no bending, since light does not reach the region behind the tip and auxin remains evenly distributed either side of the shoot (you could argue that bending may still occur if the covers are not long enough down the coleoptiles to prevent this).

Untreated coleoptiles – bend towards the right, because auxin is produced by the tip and diffuses away from the light on the left, stimulating growth on that side.

c Each coleoptile is a different starting length. Therefore to allow a fair comparison between treatments we need to find the increase in length in comparison to the starting length. We can do this by calculating a percentage increase.

CHAPTER 13

1 ▶ B **2 ▶** A **3 ▶** D **4 ▶** D

5 ▶ a Stigma

b Any two from: by the coloured petals, scent and nectar

c Pollen tube should be shown growing down through the rest of the style and entering the ovary.

6 ▶ a Independent: temperature

Dependent: height of seedlings and % of seeds that germinated

b $\frac{3.4 + 4.5 + 2.5 + 3.7 + 2.8 + 4.4 + 4.3 + 2.9 + 2.1 + 3.7}{10}$

= 3.43 cm

c Higher temperatures (20 °C or 30 °C) are needed for germination to take place. At a low temperature (4 °C) few seeds germinated or grew. Growth of seedlings was greater at 30 °C than at 20 °C.

d Temperature affects the activity of enzymes and the rate of metabolic reactions. It increases the kinetic energy of molecules, so there are more collisions between enzyme and substrate molecules, resulting in an increase in successful reactions. Germination depends on metabolic reactions, so temperature affects germination.

e The light intensity is not controlled. Tube A is in the light, while B and C are in the dark. All three tubes should be in the light (or all three in the dark).

7 ▶ a This method of reproduction does not involve flowers / seeds / pollen and ovules, so it is not sexual. It involves the tubers growing from body cells of the parent plant.

b The tubers grow from body cells of the parent plant by mitosis, which produces cells that are genetically identical.

c Growth may be affected by the environment of the plants, e.g. different soil minerals or different light intensity.

d Sexual reproduction produces offspring that show genetic variation, allowing them to survive if the environment changes.

8 ▶ **a** A = stigma, B = ovary, C = anther, D = filament

b Any three from:

- lack of large petals (no need to attract insects)
- lack of brightly coloured petals (no need to attract insects)
- exposed stamens (to catch the wind and blow pollen away)
- exposed stigma (to catch windborne pollen)
- stigma feathery (to catch pollen).

c The pollen grain produces a pollen tube, which grows down through the tissue of the style and into the ovary. The pollen tube enters an opening in an ovule. The tip of the pollen tube breaks down and the pollen grain nucleus moves out of the pollen tube into the ovule, where it fertilises the nucleus of the egg cell (ovum).

d Any four from:

- large petals
- brightly coloured petals
- stamens enclosed within flower
- stigma enclosed within flower
- stigma sticky
- nectaries present
- large, sticky pollen grains.

9 ▶ **a** Method A. Fruits are produced by flowers via sexual reproduction, which introduces genetic variation.

b Insect-pollinated. The flower has large, brightly coloured petals to attract insects.

10 ▶ **a** The banana plants reproduce asexually, so they are all genetically identical. Therefore all the plants are susceptible to the fungus, none is resistant to it.

b If the plants reproduced sexually, this would introduce genetic variation. Some of the plants might then have resistance to the fungus and would be able to survive.

c Asexual reproduction is faster than sexual reproduction, so more banana plants can be produced more quickly. (Also, if the plants *are* resistant to a disease, they all will be, so won't be killed by it.)

END OF UNIT 3 QUESTIONS

1 ▶ **a i** Any four points from:

As light intensity increases, the rate of photosynthesis increases (1). The rate of increase is faster at high CO_2 concentration than at low CO_2 concentration (1).

(At both CO_2 concentrations) the rate of photosynthesis reaches a plateau / maximum / levels off (1). At low CO_2 concentration this happens below light intensity X (1) whereas at high CO_2 concentration it happens at / above light intensity X (1).

The maximum rate of photosynthesis is higher at high CO_2 concentration than at low CO_2 concentration (1).

ii Up to X the limiting factor is light (1), because increasing light intensity increases the rate of photosynthesis (1). Beyond X the limiting factor is CO_2 (1), as increasing light intensity has no effect on the rate of photosynthesis (1) whereas increased CO_2 increases the rate (1).

b i Temperature (1), water availability (1)

ii Reactions are slow at low temperatures (1), because the molecules have little kinetic energy (1) and therefore there are fewer successful collisions between enzyme molecules and substrates (1). Water is a raw material for photosynthesis (1).

c The photosynthesis reaction uses / takes in light energy (1) and converts it into chemical energy stored in the glucose / starch produced (1).

2 ▶ **a i** To remove any water / sap on the outside of the cylinder (1)

ii To allow an average to be calculated / to check reliability of results (1)

iii So they all had the same surface area to volume ratio (1)

b i 3 mol per dm^3 sucrose solution has a lower water potential / lower concentration of water / higher concentration of solutes than potato cells (1), so water moves out of the cells and into the sucrose solution (1), resulting in a decrease in mass of the cylinder (1).

ii (Approximately) 0.75 mol per dm^3 (1), because there is no change in mass (1), as there is no net movement of water (1).

c Repeat experiment with more cylinders (1), use more concentrations of sucrose between 0 and 1 mol per dm^3 (such as 0.2 mol per dm^3, 0.4 mol per dm^3, etc.) (1)

3 ▶ **a i** (Positive) phototropism (1)

ii Any three from:

Auxin produced in tip of shoot (1) diffuses back down the shoot (1), auxin moves away from light source (1), causing growth on the dark side of the shoot (1)

iii The plant receives more light for photosynthesis (1)

b i Any two from:

Most curvature takes place at a wavelength of about 430 nm (1), light wavelengths above about 500–550 nm produce no curvature (1), there is a smaller increase in curvature with a peak at about 370 nm (1)

ii Any two for 2 marks from:

The tip / something in the tip only absorbs these wavelengths of light (1), cannot absorb other wavelengths (1), these wavelengths are present in sunlight (1)

c i Gravity (1)

ii Root grows towards gravity / positive geotropism (1), shoot (in some species) grows away from gravity / shows negative geotropism (1)

iii Shoots grow upwards towards light needed for photosynthesis (1), roots grow down towards source of water (1)

4 ▶ a i B (1) ii F (1) iii E (1)

b Any two for 2 marks:
- large petals
- brightly coloured petals
- stamens enclosed within flower
- stigma enclosed within flower.

c i H (1) ii G (1) iii C (1)

d i Pollination is the transfer of pollen from the anther to the stigma (1). Fertilisation is the fusion of the nucleus of the pollen grain with the nucleus of the ovum (1).

ii Self-pollination means transfer of pollen from the anther of a plant to the stigma of the same plant (1). Cross-pollination is when pollen from one plant is transferred to the stigma of another plant (1).

5 ▶ Any six points for 6 marks:
- pollen grains placed in sucrose solution / in range of concentrations of sucrose solutions, and pollen grains placed in water (Control)
- grains from same species / same plant / same flower
- stated number of grains in each treatment (minimum 10)
- (use microscope to) count the number of grains that germinate / grow pollen tube
- (after) suggested time period (minimum 1 hour)
- calculate % germination in each treatment
- same temperature / light intensity / other suitable controlled variable

UNIT 4 ANSWERS

CHAPTER 14

1 ▶ D 2 ▶ B 3 ▶ A

4 ▶ a Habitat: place where an organism lives; community: all the populations of living organisms in an ecosystem; environment: the non-biological components of an ecosystem; population: all the organisms of a particular species in an ecosystem

b Plants = producers; animals = consumers; decomposers = breakdown of dead material

5 ▶ a i Plankton ii Krill

b Quaternary consumer / top carnivore

c Very large amounts of photosynthesis / production by the plankton can support this number of trophic levels

6 ▶ a Any two from:
- trees → moths → small birds → owls
- trees → moths → small birds → weasels
- trees → moths → beetles → shrews

b Vole or small bird

c Reduction in dead leaves means there will be fewer earthworms and beetles, so less food for shrews

d In the pyramid of numbers there are only 200 trees, compared to hundreds of thousands of small consumers at the higher levels. However, each tree has a huge mass compared to the mass of each insect / bird / beetle, etc. so the overall mass of the trees is much larger.

7 ▶ a $\frac{125}{3050} \times 100 = 4.1\%$

b As urine / faeces and as heat from metabolic processes / respiration

c Eaten by other herbivores, or 'lost' in dead matter / passes to decomposers.

CHAPTER 15

1 ▶ B 2 ▶ A 3 ▶ C

4 ▶ Because of the great increase in the human population, the need to produce food to sustain the population, and the industrial revolution and growth of technology

5 ▶ a The concentration of carbon dioxide is increasing.

b The increase is due to increased burning of fossil fuels.

c In the summer there is more photosynthesis, which lowers the concentration of carbon dioxide. In the winter there is less photosynthesis, so carbon dioxide levels increase.

6 ▶ a Any two from: carbon dioxide, methane, water vapour, CFCs

b Without the greenhouse effect, the temperature on the Earth's surface would be much colder than it is now, and life would not be able to exist. (One estimate is that the average temperature would be 30 °C lower.)

c Malaria is spread by mosquitoes, which are found in warmer regions of the world. If global warming occurs, mosquitoes will spread to more northerly parts of Europe.

7 ▶ a Rain washes fertiliser into the pond, causing the algae to grow.

b Rain washes the fertiliser downhill away from the pond.

c Algae are photosynthetic organisms (protoctists). An increased temperature increases their rate of photosynthesis, so they grow more quickly.

8 ▶ The nitrates in sewage cause rapid growth of bacteria in the water. The bacteria need oxygen for growth – they use up the oxygen in the water, so that the fish suffocate / die.

9 ▶ a Pesticides kill pests (insects etc.) so less crop is eaten; fertilisers supply minerals that increase the growth of crops.

b Use manure as fertiliser. After the crop is has been harvested, dig in the remains of plants, allowing them to decay and release nutrients. Use crop rotation including leguminous plants to produce nitrates. Use biological control methods to reduce pests.

END OF UNIT 4 QUESTIONS

1 ▶ a i Any of the following for 1 mark:
- plankton → sea butterfly → arrow worm → herring
- plankton → small crustaceans → large crustaceans → herring
- plankton → copepods → sand eel → herring

ii Primary consumer = sea butterfly / small crustaceans / copepods (1 mark for correct organism from food chain used)
Secondary consumer = arrow worm / large crustaceans / sand eel (1 mark for correct organism from food chain used)

iii Herring (1). It is a secondary consumer when it feeds on other small crustaceans or copepods, and a tertiary consumer when it feeds on sand eels, large crustaceans or arrow worms (1).

b i Pyramid drawn correctly, with relative amounts of energy at each trophic level approximately correct (1)

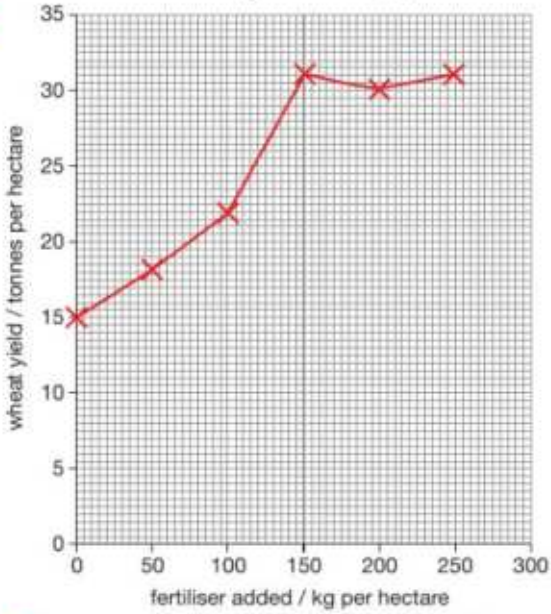
ii $\frac{892}{8869} \times 100 = 10.1\%$ (1 for correct values in calculation, 1 for answer)

iii $\frac{91}{892} \times 100 = 10.2\%$ (1 for correct values in calculation, 1 for answer)

iv $\frac{8869}{0.1} \times 100 = 8\,869\,000$ kJ (1 for correct values in calculation, 1 for answer)

v Two from: losses from respiration / in movement / as faeces / undigested food (2)

2 ▶



a Axes correct way round, scales correct (1); axes labelled, with units (1); points plotted correctly (1); points joined with straight lines (1)

b 150 kg per hectare (1). This amount gives maximum yield (1); any higher concentration would waste fertiliser / waste money (1) (since yield is not higher).

c To make proteins (1)

d Any of the following to a maximum of 5 marks:
- causes plants / algae to grow / form algal bloom
- reference to eutrophication
- plants /algae prevent light penetrating into the water
- submerged plants / algae underneath cannot photosynthesise so they die
- bacteria break down the dead plants / algae
- respiration of the bacteria uses up oxygen
- oxygen level of the water falls / water becomes anoxic
- aerobic animals / fish in the water die.

3 ▶ a i The insecticide becomes less effective / kills fewer insects over the three years (1). This is because some insects were resistant to the pesticide (1) so these reproduced / more resistant insects survived (1).

ii Intermediate concentration (1), as almost as effective as the strongest concentration (1) and will be cheaper / less polluting (1)

b i When amounts of pesticide in body tissues build up over time (1)

ii Named pesticide, e.g. DDT (1) accumulated in top carnivores / named example (e.g. osprey) (1) and caused death / other named problem (1)

iii Could bioaccumulate in human tissues / cause illness / death (1)

4 ▶ a Plants carry out photosynthesis (1), which converts carbon dioxide into organic carbon compounds (1).

b Combustion of fossil fuels, which increases carbon dioxide levels (1); deforestation, which increases carbon dioxide levels (1)

c i The bodies are broken down by respiration (1), which produces carbon dioxide (1).

ii Insects chew bodies into smaller pieces (1), providing a larger surface area (1) for enzymes produced by decomposers (1).

iii 4 marks for two sensible points from the curve, with reasons. e.g.
- curve 1 rises rapidly to a peak of CO_2 production by 7 days, whereas curve 2 shows little production during this time due to the slower action of decomposers on the intact bodies (2)
- curve 1 falls from the peak after 7 days due to material in the dead bodies being used up (1), while curve 2 shows little CO_2 production in this time (2)
- curve 2 starts to rise only at 9–12 days due to the slower action of decomposers on the intact bodies; CO_2 production in curve 1 has nearly fallen back to zero by 11 days (2)

5 ▶ a 2 marks for examples of competition, e.g. for same food source / nest sites, etc. (animals), light / minerals / water (plants) (2). Less well-adapted individuals die / best adapted survive (1) preventing population increasing / population numbers remain stable (1) (maximum 3 marks).

b i 2 marks for two from:
- mineral ions / named ion, for healthy growth
- light for photosynthesis
- water for photosynthesis / turgidity / transport.

ii To kill the weeds before they produce seeds (1) reducing the need to use more herbicide later in the season (1).

c i Species A (1), because there are more adult beetles when the parasite is absent (1)

ii The parasite kills species A (1) but does not affect numbers of species B (1). The first graph shows that species A is better at competing for resources than species B (1). The second graph shows that when species A is removed, species B can do better / increase in numbers (1).

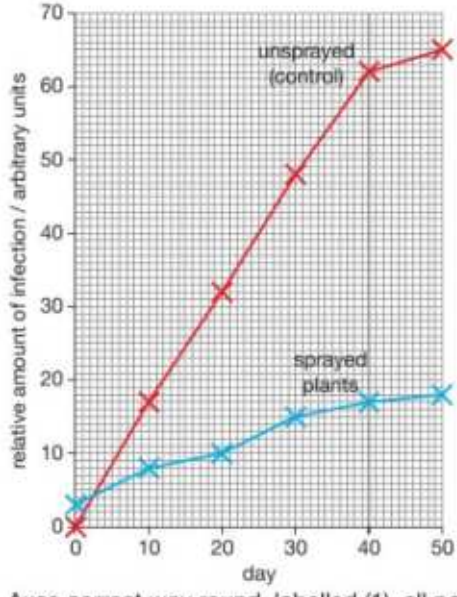
6 ▶ a $\frac{88600 - 886}{88600} \times 100 = 99\%$ (1 mark for calculation, 1 mark for answer; allow 1 mark if answer given is 1%)

b Sulfur dioxide and nitrogen oxides are acidic gases (1). They are blown long distances by winds (1) and dissolve in rain (so acidifying ground water) (1). (Deduct 1 mark if carbon monoxide given as acidic gas.)

c Dissolved / suspended solids make water cloudy / dirty (1), preventing light reaching plants (1), so plants are unable to photosynthesise (1) and therefore die (1).

7 ▶ a Reduced growth / photosynthesis (1), affecting the appearance of the crop so not harvested / unfit for sale (1)

i



Axes correct way round, labelled (1), all points correctly plotted on both curves (2), key to each curve (1), points joined by straight lines (1)

ii Sprayed: 12 (1), unsprayed 39 (1)

iii The Control shows whether there is any infection without the fungicide (1). It is needed to be able to see how much effect the fungicide is having on the infection, i.e. as a comparison (1).

iv By day 30, the infection in the unsprayed (Control) plants was approximately the same as in Year 1 (1). However the infection in the sprayed plants had increased (1). This was probably because the plants had developed resistance to the fungicide (1).

UNIT 5 ANSWERS

CHAPTER 16

1 ▶ D

2 ▶ a i A gene is a length of DNA that codes for a protein.

ii Alleles are different forms of a gene.

b A chromosome is a structure in the nucleus of a cell composed of DNA (and proteins).

c i Both have 23 pairs of chromosomes in each cell.

ii A woman's skin cells contain XX sex chromosomes, a man's contain XY.

CHAPTER 17

1 ▶ D 2 ▶ B 3 ▶ C 4 ▶ B

5 ▶ a Both types of division start with each chromosome copying itself / DNA replicating / DNA copying itself / chromatids forming.

Plus any two from:

- Mitosis produces two daughter cells, meiosis produces four daughter cells.
- Daughter cells from mitosis are genetically identical to each other and the parent cell; daughter cells from meiosis are genetically different from each other and the parent cell.
- Mitosis produces daughter cells with the same number of chromosomes as the parent cell / diploid to diploid; meiosis halves the chromosome number / diploid to haploid.

b Mitosis: they are formed by division of body cells to produce more body cells.

c Because the number of chromosomes per cell is reduced by half.

6 ▶ a They have been formed by mitosis, so are genetically identical.

b Meiosis is used to form pollen and egg cells, so fertilisation results in seeds that are genetically different from each other.

7 ▶ a Control

b Plants from cuttings will be genetically identical, so it will be easier to see the effects of the treatment with nitrogen-fixing bacteria. Plants from seeds would be genetically different, so their growth might depend on their genes, rather than the treatment.

c The nitrogen-fixing bacteria provide nitrates needed for growth. This is an environmental effect on growth, rather than a genetic one. Therefore the environment plays a big part in the growth of these plants.

8 ▶ a Meiosis, because sperm are gametes that are haploid / contain half the number of chromosomes of body cells.

b Mitosis, because body cells are dividing to produce more body cells with the normal chromosome number.

c Mitosis, because body cells are dividing to produce more body cells with the normal chromosome number.

d Meiosis, because pollen grains are gametes that are haploid / contain half the number of chromosomes of the plant's body cells.

e Mitosis, because the zygote must divide to produce more body cells with the normal chromosome number.

9 ▶ a Genetic – eye colour is inherited and not affected by the environment.

b Genetic – it depends on inheriting XX or XY chromosomes.

c Environmental – the pH of soil is a feature of the plant's environment.

d Both – genes determine whether a plant falls into the tall or dwarf category, but environmental factors affect how well each plant grows.

e Both – genes affect the risk level, but environmental factors such as diet, smoking, etc. also have an effect.

10 ▶ a Chromosomes align themselves along the equator of the cell, attached to the spindle fibres.

b Spindle fibres shorten and pull chromatids towards opposite poles of the cell.

c Chromosomes reach the opposite poles of the cell. Nucleus starts to re-form.

CHAPTER 18

1 ▶ D **2 ▶** A **3 ▶** D

4 ▶ a All tall

b All tall

c All tall

d 3 tall : 1 short

e 1 tall : 1 short (or 2 : 2)

f All short

5 ▶ a i Homozygous

ii A dominant gene hides the expression of the recessive gene in heterozygous individuals; a recessive gene is expressed only in homozygous individuals.

b i B and b **ii** All Bb

c i Heterozygous

ii

	B	b
B	BB	Bb
b	Bb	bb

Phenotypes = 3 black : 1 red.

6 ▶ a Gametes of parents = R and r
Genotypes of F1 = Rr
Genotypes of F1 parents = Rr and Rr
Gametes of F1 parents R, r and R, r
Genotypes of F2 =

	R	r
R	RR	Rr
r	Rr	rr

b A, B and C are red, D is yellow

7 ▶ a Individual 8 has cystic fibrosis, but neither of his parents does, so they must be heterozygous and the allele must be recessive. If the allele was dominant, he would have to have inherited at least one dominant allele from one parent, so that parent would have cystic fibrosis too.

b 3 and 4 must be heterozygous for the gene, as they do not have the disease, but their son does. 11 must be homozygous for the gene, since she has the disease.

c i Probability that the next child will be male is 1 in 2, or 0.5:

	X	Y
X	XX	XY
X	XX	XY

ii Let A = the normal allele of the gene and a = cystic fibrosis gene.

Individual 11's genotype = aa. Individual 10's genotype could be AA or Aa.

So there are two possible outcomes:

AA × aa

	A	A
a	Aa	Aa
a	Aa	Aa

Aa × aa

	A	a
a	Aa	aa
a	Aa	aa

Depending on whether 10 is AA or Aa, there could be no chance, or a 1 in 2 chance (0.5 probability) of their next child having cystic fibrosis. It could also be argued that, since the genotype of 10 is unknown, the probability of the child having cystic fibrosis is 1 in 4, or 0.25.

8 ▶ a Both parents must be heterozygous. Let S = allele for short hair and s = allele for long hair.

	S	s
S	SS	Ss
s	Ss	ss

There is a 1 in 4 chance of producing a long-haired guinea pig (ss).

b Breed the short-haired guinea pig with a homozygous long-haired guinea pig (ss). If it is heterozygous (Ss), both long-haired and short-haired offspring will be produced (in a 1:1 ratio):

	S	s
s	Ss	ss
s	Ss	ss

If it is homozygous (SS), all offspring will have short hair:

	S	S
s	Ss	Ss
s	Ss	Ss

CHAPTER 19

1 ▶ D **2** ▶ B **3** ▶ A **4** ▶ D
5 ▶ D **6** ▶ B

7 ▶ **a** It means that the organisms that are best adapted to their environment are more likely to survive and reproduce.

b Darwin and Wallace

8 ▶ **a** An organism that causes disease

b Fungi and bacteria

c Random mutations produce some bacteria that are resistant to an antibiotic. If the antibiotic continues to be used, the resistant bacteria will survive and the non-resistant ones will be killed. The resistant bacteria have a selective advantage over the non-resistant bacteria; they quickly reproduce and cause disease.

9 ▶ **a** Rats with the mutant allele, that made them resistant to warfarin, survived and reproduced, so now many more rats carry the allele. Rats without the allele did not survive to reproduce.

b It would decrease as it would not give an advantage; rats that don't have the allele will breed equally well. (In fact, rats with the warfarin-resistant allele have a selective disadvantage when warfarin is not being used, although students will not know this.)

10 ▶ **a** They have a heavy beak, which is adapted to crush seeds.

b They have a long, narrow beak, which can be used to probe under the bark of trees for insects.

c Ancestors showed slight variations in their beaks. Where the variation enabled a bird to catch insects, or eat leaves and other food better than birds with other types of beak, the birds survived better and reproduced (survival of the fittest), passing on their genes for the adaptation. Eventually groups of birds became so different from members of other groups that they couldn't interbreed, and formed new species.

11 ▶ **a** As a result of (random) mutations

b **i** Selection pressure: a factor in the environment that affects the fitness of an organism. In this case the presence of toxic metals means that the non-tolerant plants will be killed and so do not reproduce to pass on their genes.

ii Selective advantage: varieties that survive in the presence of a selection pressure are said to have a selective advantage. In this example the plants that are tolerant to toxic metals have a selective advantage when compared with the non-tolerant plants.

iii Natural selection: the overall process that, when metals are present, results in fewer non-tolerant plants and an increase in the number of tolerant plants. If it continues, natural selection results in evolution.

c When there are no toxic metals, the metal-tolerant plants must have some sort of selective disadvantage over the non-tolerant ones. For example, they may need to use metabolic energy (ATP) to protect their cells against metals or get rid of metal ions. If there are no metal ions in the soil, this is a waste of resources.

12 ▶ **a** Both involve selection of which animals or plants survive to breed.

b In selective breeding the farmer / breeder does the selection. In natural selection it is the survival of the fittest in a habitat that leads to selection.

13 ▶ **a** Milk yield and feed to milk conversion rate

b Choose a cow with the best characteristics (i.e. feed to meat conversion rate, meat : fat ratio, growth rate and total body mass) and give hormone / FSH injections to cause multiple ovulations. Collect ova and use IVF to fertilise with sperm collected from a bull with the best characteristics. Separate cells of embryos that develop and produce large numbers of embryos. Screen for sex (males) and implant into surrogate mother cows.

14 ▶ **a** Hybrid G was produced by selective breeding. Individual plants from pure lines of A and B were selected (for size of cobs) and crossed to produce hybrid E. Similarly, individual plants from pure lines of C and D were selected and crossed to produce hybrid F. Plants from hybrids E and F were then selected for their cob size and crossed to produce hybrid G. (Crossing would be done by transfer of pollen from anthers to stigmas of plants.)

b Cobs from hybrid G are larger, they have more seeds and the cobs are more uniform size / shape.

c Any sensible suggestion, e.g. breed from each under identical environmental conditions, or sequence the genes to show differences.

15 ▶ The essay should include:

- examples of traditional selective breeding of crop plants or domestic animals
- advantages of this type of artificial selection, e.g. to crop yield, characteristics of animals
- cloning of plants and its advantages
- cloning animals and its uses
- causes for concern with cloned organisms (e.g. cloned plants all genetically identical, so susceptible to same pathogens; cloned animals like 'Dolly' may have genetic defects; ethical issues).

END OF UNIT 5 QUESTIONS

1 ▶ **a** Toxic copper ions (1), only copper-tolerant plants will grow and reproduce / non-tolerant plants will die (1)

b Predation by lions (1), only those wildebeest that are fast runners (or equivalent) will survive and reproduce / slow animals will be killed and not reproduce (1)

c Presence of pesticide (1), only those pests resistant to the pesticide will grow and reproduce / non-resistant pests will die (1)

2 ▶ **a** Both 1 and 2 are tasters (1). If the gene was recessive, all their children would also be tasters, but 4 is a non-taster (1 mark for explanation or correct genetic diagram).

b Individual 3 is Tt (1), because if TT, she couldn't supply a 't' allele to have daughters who are non-tasters (1). Individual 7 is tt (1), because this is the only genotype that produces a taster (1).

c Individual 5 could be either TT or Tt (1), since her husband 6 is a non-taster (tt), and so she could donate a 'T' allele from either genotype to produce a son who is Tt (1 mark for explanation or correct genetic diagram).

d Individual 3 must have the genotype Tt (1). Individual 4 must be tt (1). So the cross produces a 1:1 ratio of tasters to non-tasters / probability is 0.5 that a child is a taster (1). (1 mark for correct genetic diagram):

	T	t
t	Tt	tt
t	Tt	tt

3 ▶ a D, C, B, E, F, A (all correct = 2 marks, 1 mark if one or more wrong)

b Mitosis (1), because there are only two cells produced / only one division / no reduction division / no pairing of homologous chromosomes (1)

c 46

d Any two from:

- mitosis produces two daughter cells; meiosis produces four daughter cells
- daughter cells from mitosis are genetically identical to each other and the parent cell; daughter cells from meiosis are genetically different from each other and the parent cell
- mitosis produces daughter cells with the same number of chromosomes as the parent cell / diploid to diploid; meiosis halves the chromosome number / diploid to haploid.

UNIT 6 ANSWERS

CHAPTER 20

1 ▶ B **2 ▶** C **3 ▶** D

4 ▶ a Using (hot) steam under high pressure

b The air is needed to supply oxygen for aerobic respiration of the microorganisms. It is filtered to prevent contamination by unwanted microorganisms.

c Microorganisms produce metabolic heat that could overheat the culture. The water jacket contains circulating cold water to cool the contents of the fermenter and maintain a constant temperature.

d Nutrients

e Growth would be reduced. The paddles mix the contents, so that the *Penicillium* cells are exposed to more nutrients, achieving a faster rate of growth.

5 ▶ a To kill any natural bacteria in the milk.

b It is the optimum temperature for growth and activity of the yoghurt bacteria.

c Proteins in the milk coagulate due to the fall in pH.

d The drop in pH reduces the growth of the lactic acid bacteria.

e The low pH helps to prevent the growth of other spoiling microorganisms.

CHAPTER 21

1 ▶ B **2 ▶** C **3 ▶** D **4 ▶** A

5 ▶ a 1 = restriction endonuclease / restriction enzyme; 2 = (DNA) ligase

b It is a vector, used to transfer the gene into the bacterium.

c They are cultured in fermenters.

d It is identical to human insulin and gives better control of blood glucose levels.

6 ▶ The account should discuss how far xenotransplantation has been developed and what advantages have been suggested for it. It should look at what the biological problems might be, and the ethical objections. It should be a balanced account.

7 ▶ a Use *Agrobacterium* to insert plasmids containing the required gene into plant cells, or use a gene gun to fire a pellet of gold, coated with DNA containing the required gene, into the plant tissue.

b The plants are grown by micropropagation.

c Egg cell

8 ▶ Essay should describe a range of genetically engineered products, such as:

- products from bacteria: human insulin, enzymes, human growth hormone, etc.
- genetically modified plants, such as 'golden rice' and crops resistant to herbicide
- genetically modified animals, e.g. sheep used to produce human proteins, xenotransplantation.

The benefits of each example should be discussed.

The risks from genetic engineering should also be discussed, such as:

- 'escape' of genes from crop plants into natural plant populations
- transfer of 'hidden' pathogens in xenotransplanted organs.

END OF UNIT 6 QUESTIONS

1 ▶ a Restriction endonuclease / restriction enzyme (1)

b An egg cell / egg (1), with its nucleus removed (1)

c An organism containing a gene / DNA / an allele from a different species (1)

d Any three points for 3 marks:

- all sheep will be genetically identical / have same genes / have same DNA
- all sheep will produce Factor IX
- could be used to make more Factor IX
- faster reproduction of sheep
- only need to genetically modify the sheep once.

e Prevents blood loss (1); prevents entry of pathogens / bacteria / microorganisms (1)

f Plasma and platelets (2)

2 ▶ a It would not be possible to destroy these plants (1), and the genes could jump to other species so that they would also not be able to be destroyed (1).

b The plants could spread to other areas and would increase in numbers, as they were resistant to pests (1). The genes could jump to other species and they would also spread (1).

c The plants could spread to other areas and would compete with other species and take over other habitats (1). The genes could jump to other species and they would also compete with other species (1).

3 ▶ a To supply oxygen for aerobic respiration of the microorganisms (1).

b The temperature must be at the optimum for the enzymes in the microorganisms to work (1). If temperature is too low, reactions will be slow / if too high enzymes will be denatured / microorganisms killed (1).

c pH / supply of nutrients (1)

d Disinfectants are difficult to wash out of the fermenter (1) and might kill the microorganism being grown (1) (steam just leaves harmless water).

e 2 marks for any two from: human insulin works better than insulin from animal pancreases / there is no risk of transfer of pathogens using human insulin / using human insulin from microorganisms is acceptable to people who object to using animal tissues.

4 ▶ a i A small ring of DNA (1) in (the cytoplasm of) a bacterium (1)

ii A virus (1) that infects bacterial cells (1)

b i Four points from the following, for maximum of 4 marks: restriction endonucleases are enzymes that cut DNA at specific points (1). They are used to cut out genes from the DNA (1) by recognising a certain base sequence (1). Different restriction enzymes cut DNA at different places (1). Use of the same restriction enzyme on a plasmid allows the DNA to be inserted into the plasmid (1).

ii Ligases are enzymes that join cut ends of DNA (1) allowing genes to be put into plasmids (1).

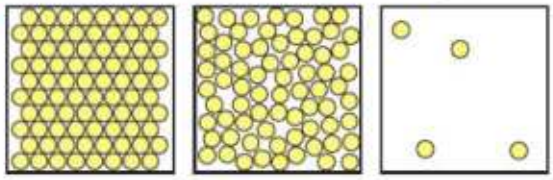
CHEMISTRY

UNIT 1 ANSWERS

CHAPTER 1

1 ▶ **a** melting **b** freezing
c subliming / sublimation **d** subliming / sublimation

2 ▶ **a**



solid liquid gas

Note: Solids should have regularly packed particles touching. Liquids should have most of the particles touching at least some of their neighbours, but with gaps here and there, and no regularity. Gases should have the particles well spaced.

b Solids: vibration around a fixed point. Liquids: particles can move around into vacant spaces, but with some difficulty because of the relatively close packing.

c Evaporation: Some faster moving particles break away from the surface of the liquid. Boiling: Attractive forces are broken throughout the liquid to produce bubbles of vapour.

3 ▶ **a** **i** A – gas; B – liquid; C – solid; D – liquid; E – solid
ii A – gas; B – solid; C – solid; D – liquid; E – solid
iii A – gas; B – liquid; C – solid; D – gas; E – solid

b A, because it is a gas.

c It sublimes and therefore is converted directly from a solid to a gas without going through the liquid stage.

d D – it has a lower boiling point, so the forces of attraction between particles will be weaker and it will evaporate more easily than substance B (the only other substance that is a liquid at 25 °C).

4 ▶ **a** The ammonia and hydrogen chloride particles have to diffuse through the air in the tube, colliding with air particles all the way.

b **i** Its particles will move faster.
ii It would take slightly longer for the white ring to form, because the gas particles would be moving more slowly at the lower temperature.

c Ammonia particles are lighter than hydrogen chloride particles and so move faster. The ammonia covers more distance than the hydrogen chloride in the same time.

d **i** Ammonium bromide
ii The heavier hydrogen bromide particles would move more slowly than the hydrogen chloride particles, and so the ring would form even closer to the hydrobromic acid end than it was to the hydrochloric acid end. The ring will also take slightly longer to form because of the slower moving particles.

CHAPTER 2

1 ▶

Element	Compound	Mixture
hydrogen	magnesium oxide	sea water
calcium	copper(II) sulfate	honey
		blood
		mud
		potassium iodide solution

2 ▶ **a** mixture **b** mixture **c** element
d element **e** compound **f** compound

3 ▶ Substance X is the pure substance – it melts at a fixed temperature. Substance Y is impure – it melts over a range of temperatures.

4 ▶ **a** crystallisation **b** (simple) distillation
c fractional distillation **d** chromatography
e filtration

5 ▶ For example: Stir with a large enough volume of cold water to dissolve all the sugar. Filter to leave the diamonds on the filter paper. Wash on the filter paper with more water to remove any last traces of sugar solution. Allow to dry.

6 ▶ **a** M **b** R
c 0.45 ±0.01 (measure to the centre of the spot and remember to measure from the base line and not from the bottom of the paper)
d G and T **e** P

CHAPTER 3

1 ▶ **a** the nucleus **b** electrons
c proton **d** proton and neutron

2 ▶ **a** 9
b sum of protons + neutrons in the nucleus
c 9p, 10n, 9e
d The protons and electrons have equal but opposite charges. The atom has no overall charge, therefore there must be equal numbers of protons and electrons.

3 ▶ **a** 26p, 30n, 26e
b 41p, 52n, 41e
c 92p, 143n, 92e

4 ▶ **a** Atoms with the same atomic number but different mass numbers. They have the same number of protons, but different numbers of neutrons.
b 35Cl: 17p, 18n, 17e; 37Cl: 17p, 20n, 17e

5 ▶ $\frac{6 \times 7 + 93 \times 7}{100} = 6.93$

6 ▶ $\frac{24 \times 78.99 + 25 \times 10.00 + 26 \times 11.01}{100} = 24.32$

7 ▶ $\frac{204 \times 1.4 + 206 \times 24.1 + 207 \times 22.1 + 208 \times 52.4}{100} = 207.241$

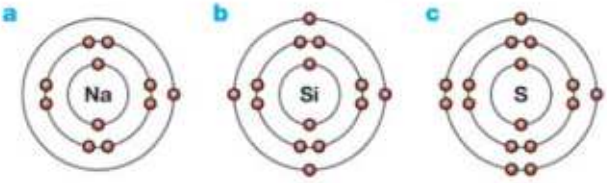
8 ▶ **a** 77 protons, 114 neutrons, 77 electrons
b Iridium-193 has 2 more neutrons in the nucleus.
c More iridium-193 because the relative atomic mass is closer to 193 than 191.

9 ▶ This statement is true – it only applies to 1 element, hydrogen (^{1}H).

CHAPTER 4

1 ▶ **a** **i** strontium **ii** chlorine **iii** nitrogen **iv** caesium **v** neon
b metals: caesium, molybdenum, nickel, strontium, tin
non-metals: chlorine, neon, nitrogen

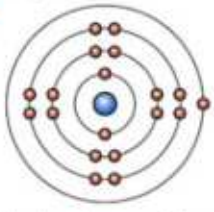
2 ▶ **a** **b** **c**



3 ▶ **a** 2, 7 **b** 2, 8, 3 **c** 2, 8, 8, 2

4 ▶ **a** 5 **b** 7 **c** 4 **d** 8

5 ▶ **a** A and F because they have 4 electrons in their outer shell
b A
c C and D because 5 shells are occupied
d C because there are 7 electrons in the outer shell (energy level)
e B, D
f Calcium – it has 20 electrons, so it must have 20 protons in the nucleus. The atomic number is therefore 20. Calcium is the element with atomic number 20.
g 82, lead
h



6 ▶ Palladium is a metal and so is likely to have any of the following properties:
- good conductor of electricity
- forms a basic oxide
- is shiny when polished or freshly cut
- is malleable
- is ductile
- is a good conductor of heat

The first two are mentioned specifically on the syllabus.

7 ▶ They have a full outer shell (energy level) and so they have no tendency to form compounds by losing / gaining electrons or sharing electrons.

8 ▶ Argon and potassium OR iodine and tellurium.
The elements would then be in a different group in the Periodic Table. They would not have the same number of electrons in the outer shell as other members of the group and would react in a completely different way. For example, potassium would be in Group 0 with the noble gases, and argon, which is very unreactive, would be in Group 1, with the highly reactive alkali metals.

CHAPTER 5

1 ▶ **a** $Fe + 2HCl \rightarrow FeCl_2 + H_2$
b $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
c $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$
d $2Al + Cr_2O_3 \rightarrow Al_2O_3 + 2Cr$
e $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
f $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2CO_2 + 2H_2O$
g $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$
h $Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$
i $Pb + 2AgNO_3 \rightarrow Pb(NO_3)_2 + 2Ag$
j $2AgNO_3 + MgCl_2 \rightarrow Mg(NO_3)_2 + 2AgCl$
k $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

2 ▶ **a** 44 **b** 60 **c** 142 **d** 132
e 286 (The common mistake would be not to multiply the whole water molecule by 10. So the mass of the $10H_2O$ is 180. Students will commonly and wrongly come up with 36 for this by multiplying the H_2 by 10 but not the O as well. Work out the mass of the whole H_2O first and then multiply it by the number in front. That way you won't make this mistake.)
f 392

3 ▶ **a** 13.9% **b** 35%
c 21.2% (Be careful of the cases where there are two nitrogen atoms in the fertiliser (all except KNO_3). The masses of the nitrogen in those cases will be 28 and not 14.)

4 ▶ In each case, work out the M_r by adding up the relative atomic masses (A_r values), and then attach the unit 'g' to give the mass of 1 mole.
a 27 g
b 331 g
c 4.30 × 16 = 68.8 g
d 0.70 × 62 = 43.4 g
e 0.015 × 85 = 1.275 g
f 0.24 × 286 = 68.64 g (Don't forget the water of crystallisation)
Strictly speaking the answers to *d)*, *e)* and *f)* shouldn't be quoted to more than 2 significant figures, because the number of moles is only quoted to that precision.)

5 ▶ In each case, work out the mass of 1 mole as above, and then work out how many moles you've got in the stated mass. You can use the equation:

$$\text{number of moles} = \frac{\text{mass}}{\text{mass of 1 mole}}$$

a $\frac{20}{40} = 0.5\,\text{mol}$

b $\frac{3.20}{160} = 0.0200\,\text{mol}$

c $\frac{2000}{79.5} = 25.2\,\text{mol}$ (Don't forget to convert kg to g.)

d $\frac{50}{249.5} = 0.2\,\text{mol}$

e $\frac{1\,000\,000}{56} = 17\,900\,\text{mol}$ (or 17 857, although this is precise to more significant figures than the A_r).

f $\frac{0.032}{64} = 5.0 \times 10^{-4}\,\text{mol}$ (0.0005 mol)

6 ▶ **a** $4 \times 58.5 = 234\,\text{g}$

b $\frac{37}{74} = 0.5\,\text{mol}$

c $\frac{1000}{40} = 25\,\text{mol}$

d $0.125 \times 79.5 = 9.94\,\text{g}$ (9.9375 g)

e $\frac{4}{0.1} = 40\,\text{g}$

f $\frac{1}{0.004} = 250\,\text{g}$

7 ▶ **a**

	P	H
Combining mass	9.39 g	0.61 g
No. of moles of atoms	$\frac{9.39}{31} = 0.30$	$\frac{0.61}{1} = 0.61$
Ratio of moles	1	2

Empirical formula is PH_2

b

	K	N	O
Combining mass	5.85 g	2.10 g	4.80 g
No. of moles of atoms	$\frac{5.85}{39} = 0.15$	$\frac{2.10}{14} = 0.15$	$\frac{4.80}{16} = 0.3$
Ratio of moles	1	1	2

Empirical formula is KNO_2

c

	Na	S	O
Combining mass	3.22 g	4.48 g	3.36 g
No. of moles of atoms	$\frac{3.22}{23} = 0.14$	$\frac{4.48}{32} = 0.14$	$\frac{3.36}{16} = 0.21$
Ratio of moles	1 simplifies to 2	1 2	1.5 3

Empirical formula is $Na_2S_2O_3$

d

	C	H	Br
Given %	22.0	4.6	73.4
No. of moles of atoms	$\frac{22.0}{12} = 1.833$	$\frac{4.6}{1} = 4.6$	$\frac{73.4}{80} = 0.9175$
Ratio of moles	2	5	1

Empirical formula is C_2H_5Br

8 ▶ **a** The mass of oxygen is 2.84–1.24 = 1.60 g

	P	O
Combining mass	1.24 g	1.60 g
No. of moles of atoms	$\frac{1.24}{31} = 0.04$	$\frac{1.60}{16} = 0.10$
Ratio of moles	1	2.5

Whole numbers must be used, therefore multiply by 2 to get the empirical formula P_2O_5.

b P_2O_5 has an M_r of 142

$$\frac{284}{142} = 2$$

Therefore there must be two lots of the empirical formula in a molecule.

Molecular formula is P_4O_{10}

9 ▶ **a**

	Carbon	Hydrogen	Oxygen
Given %	66.7	11.1	22.2
Combining mass in 100 g	66.7 g	11.1 g	22.2 g
No. of moles of atoms	$\frac{66.7}{12} = 5.558$	$\frac{11.1}{1} = 11.1$	$\frac{22.2}{16} = 1.3875$
Ratio of moles	4	8	1

Empirical formula is C_4H_8O

b The mass of the empirical formula is $4 \times 12 + 8 \times 1 + 16 = 72$. Since this is equal to the relative formula mass, the molecular formula is the same as the empirical formula, that is C_4H_8O.

10 ▶ You know the mass of anhydrous sodium sulfate (1.42 g).
You can work out the mass of water of crystallisation (3.22 – 1.42 g = 1.8 g).
You can work out the mass of 1 mole of sodium sulfate, Na_2SO_4 = 142 g;
and the mass of 1 mole of water = 18 g

Number of moles of sodium sulfate = $\frac{1.42}{142} = 0.01\,\text{mol}$

Number of moles of water = $\frac{1.8}{18} = 0.1\,\text{mol}$

So for every 1 mole of sodium sulfate, there are 10 moles of water.
The value of n is 10.

11 ▶ mass of anhydrous calcium sulfate = 44.14 – 37.34 = 6.80 g
mass of water of crystallisation = 45.94 – 44.14 = 1.80 g

mass of 1 mole of calcium sulfate, $CaSO_4$ = 136 g

number of moles of sodium sulfate = $\frac{6.80}{136}$ = 0.05 mol

mass of 1 mole of water = 18 g

number of moles of water = $\frac{1.8}{18}$ = 0.1 mol

number of moles of water = 0.1

number of moles of calcium sulfate = 0.05

the value of n = 2

12 ▶ a 0.36 mol

b From the chemical equation, the number 2 in front of the HCl indicates that 2 mol HCl react with 1 mol $CaCO_3$, therefore 0.4 mol $CaCO_3$ react with $2 \times 0.4 = 0.8$ mol HCl.

c 6 mol HCl react to form 3 mol H_2S

Therefore the number of moles of H_2S is half the number of moles of HCl.

0.4 mol HCl form 0.2 mol H_2S

d 3 mol CO form 2 mol Fe

The number of moles of Fe is $\frac{2}{3}$ the number of moles of CO.

$0.9 \times \frac{2}{3}$ = 0.6 mol iron

e $0.8 \times \frac{3}{2}$ = 1.2 mol hydrogen

13 ▶ a number of moles of iron = $\frac{10}{56}$ = 0.179 mol

b From the chemical equation, the number of moles of bromine that reacted with this number of moles of iron is $\frac{3}{2} \times 0.179 = 0.277$ mol.

c From the chemical equation, the number of moles of $FeBr_3$ will be the same as the number of moles of iron = 0.179 mol.

d mass of 1 mol $FeBr_3 = 56 + 3 \times 80 = 296$

mass of $FeBr_3 = 0.179 \times 296 = 53$ g

(A common mistake here is to multiply the number of moles of $FeBr_3$ by the mass of $2FeBr_3$. The 2 has already been used when you worked out that 2 mol Fe formed 2 mol $FeBr_3$ – do not use it again. The equation for working out the mass is

mass = number of moles × mass of **1** mole.)

14 ▶ a $\frac{1.0}{190}$ = 0.0053 mol

b 0.0053 mol

c $0.0053 \times 48 = 0.25$ g

d number of moles of NaCl = $0.0053 \times 4 = 0.0212$ mol

mass of NaCl = $0.0212 \times 58.5 = 1.2$ g

e You can carry out a moles calculation as above:

1 tonne = 1 000 000 g

moles of $TiCl_4$ = $\frac{1\,000\,000}{190}$ = 5300 mol

moles of Ti = 5300 mol

mass of Ti = $5300 \times 48 = 254\,400$ g

Alternatively, you can reason that, if 1 g $TiCl_4$ forms 0.25 g Ti, 1 tonne $TiCl_4$ will form 0.25 tonne Ti.

15 ▶ mass of 1 mole of $AlCl_3 = 27 + 3 \times 35.5 = 133.5$ g

moles of aluminum chloride = $\frac{2.67}{133.5}$ = 0.0200 mol

moles of AgCl = $3 \times 0.0200 = 0.0600$ mol

mass of 1 mole of AgCl = 108 + 35.5 = 143.5 g

mass of AgCl = $0.0600 \times 143.5 = 8.61$ g

16 ▶ a mass of 1 mol $Cr_2O_3 = 2 \times 52 + 3 \times 16 = 152$ g

number of moles of Cr_2O_3 = $\frac{50}{152}$ = 0.33 mol

number of moles of Al = $2 \times 0.33 = 0.66$ mol

mass of Al = $0.66 \times 27 = 17.8$ g

b number of moles of Cr = $2 \times 0.33 = 0.66$ mol

mass of Cr = $0.66 \times 52 = 34.3$ g

c 5 kg is 5000 g

number of moles of Cr_2O_3 = $\frac{5000}{152}$ = 33 mol

number of moles of Cr = $2 \times 33 = 66$ mol

mass of Cr = $66 \times 52 = 3430$ g or 3.43 kg

Alternatively, we can reason that 5 kg is 100 times as much as 50 g. If we start with 100 times as much Cr_2O_3, we will make 100 times as much Cr.

d 5 tonnes is 5 000 000 g

number of moles of Cr_2O_3 = $\frac{5\,000\,000}{152}$ = 33 000 mol

number of moles of Cr = $2 \times 33000 = 66000$ mol

mass of Cr = $66000 \times 52 = 3\,430\,000$ g or 3.43 tonnes

Alternatively, we can reason that, if 5 kg of Cr_2O_3 produces 3.43 kg Cr, then 5 tonnes of Cr_2O_3 will produce 3.43 tonnes of Cr.

17 ▶ a mass of 1 mol CuO = 63.5 + 16 = 79.5 g

number of moles of CuO = $\frac{4.00}{79.5}$ = 0.0503 mol

number of moles of $CuSO_4$ = 0.0503 mol

number of moles of $CuSO_4.5H_2O$ = 0.0503 mol

mass of 1 mol $CuSO_4.5H_2O = 63.5 + 32 + 4 \times 16 + 5 \times (16 + 2) = 249.5$ g

mass of $CuSO_4.5H_2O = 0.0503 \times 249.5 = 12.55$ g

b the theoretical yield is 12.55 g

the actual yield is 11.25 g

$\frac{11.25}{12.55} \times 100 = 89.64\%$

18 ▶ a mass of 1 mol ethanol = $2 \times 12 + 6 \times 1 + 16 = 46$ g

number of moles of ethanol = $\frac{20.0}{46}$ = 0.435 mol

number of moles of ethyl ethanoate = 0.435 mol

mass of 1 mol ethyl ethanoate = $4 \times 12 + 2 \times 16 + 8 \times 1 = 88$ g

mass of ethyl ethanoate = $0.435 \times 88 = 38.3$ g

b theoretical yield = 38.3 g

actual yield = 30.0 g

percentage yield = $\frac{30.0}{38.3} \times 100 = 78.3\%$

19 ▶ a 0.5 mol HCl would react with 0.25 mol Na_2CO_3.

There is more than 0.25 mol Na_2CO_3, therefore Na_2CO_3 is in excess.

b 0.02 mol O_2 would react with $\frac{0.02}{5} = 0.004$ mol C_3H_8.

There is more than 0.004 mol C_3H_8, therefore C_3H_8 is in excess.

c 28 g of CO is $\frac{28}{28} = 1$ mol

1 mol CO would react with $\frac{1}{3} = 0.33$ mol Fe_2O_3.

There is more than 0.33 mol Fe_2O_3, therefore Fe_2O_3 is in excess.

d 16 g O_2 is $\frac{16}{32} = 0.5$ mol

16 g SO_2 is $\frac{16}{64} = 0.25$ mol

0.25 mol SO_2 would react with 0.125 mol O_2

There is more than 0.125 mol O_2, therefore O_2 is in excess.

20 ▶ a 1.0 g of $CaCO_3$ is $\frac{1.0}{100} = 0.010$ mol

0.010 mol $CaCO_3$ would react with $2 \times 0.010 = 0.020$ mol HCl

There is less than 0.020 mol HCl, therefore there is not enough HCl to react with all the $CaCO_3$. Therefore $CaCO_3$ is in excess.

b To calculate the number of moles of CO_2 you must use the number of moles of HCl because not all the $CaCO_3$ reacted.

moles of HCl = 0.015 mol

moles of $CO_2 = 0.5 \times 0.015 = 0.0075$ mol

mass of $CO_2 = 0.0075 \times 44 = 0.33$ g

(If you got the answer 0.44 g you used the number of moles of $CaCO_3$. $CaCO_3$ was in excess; therefore not all of it will react.)

CHAPTER 6

1 ▶ a i An atom or group of atoms which carries an electrical charge.

ii Attractions between positively and negatively charged ions holding them together.

b Correct electronic structures for:

i Na 2,8,1 and Cl 2,8,7

ii Li 2,1 and O 2,6

iii Mg 2,8,2 and F 2,7.

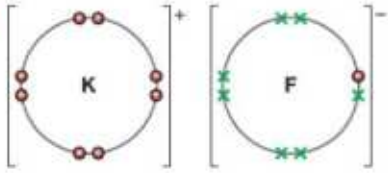
Diagrams (similar to those in the chapter) showing transfer of electrons, and the charges and electronic structures of the ions formed (or words to the same effect).

In (i), show 1 electron transferred from Na to Cl leaving Na^+ $[2,8]^+$ and Cl^- $[2,8,8]$

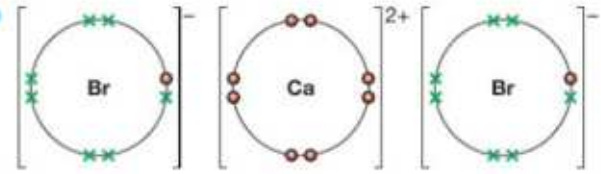
In (ii), show 2 lithium atoms each giving 1 electron to O leaving $2 \times Li^+$ $(2)^+$ and O^{2-} $[2,8]^{2-}$

In (iii), show 1 Mg giving an electron each to 2 fluorines leaving Mg^{2+} $[2,8]^{2+}$ and $2 \times F^-$ $[2,8]^-$

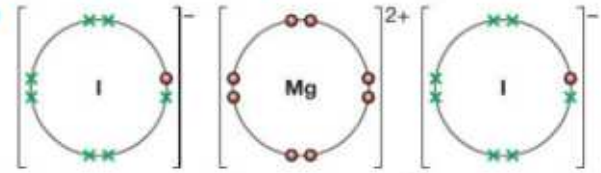
2 ▶ a



b



c



3 ▶

		a formula	b name
i	magnesium	Mg^{2+}	
ii	strontium	Sr^{2+}	
iii	potassium	K^+	
iv	oxygen	O^{2-}	oxide
v	sulfur	S^{2-}	sulfide
vi	caesium	Cs^+	
vii	chlorine	Cl^-	chloride
viii	iodine	I^-	iodide
ix	aluminium	Al^{3+}	
x	calcium	Ca^{2+}	
xi	nitrogen	N^{3-}	nitride

4 ▶

PbO	NaBr
$MgSO_4$	$ZnCl_2$
K_2CO_3	$(NH_4)_2S$
$Ca(NO_3)_2$	$Fe(OH)_3$
$FeSO_4$	$CuCO_3$
$Al_2(SO_4)_3$	$Ca(OH)_2$
$CoCl_2$	CaO
$AgNO_3$	FeF_3
NH_4NO_3	RbI
Na_2SO_4	Cr_2O_3

5 ▶ a The electrostatic forces of attraction between oppositely charged ions are strong and require a lot of energy to break.

b The ions are held tightly in place in the giant lattice structure and are not free to move.

c The ions are free to move (it is important to use the word **ions** here; any mention of electrons will score 0 in an exam).

6 ▶ Potassium chloride will have a lower melting point than calcium oxide. The charges on the ions in KCl (K^+ and Cl^-) are lower than in CaO (Ca^{2+} and O^{2-}). There are weaker electrostatic forces of attraction between oppositely charged ions in KCl than in CaO; these forces require less energy to break than the forces in CaO.

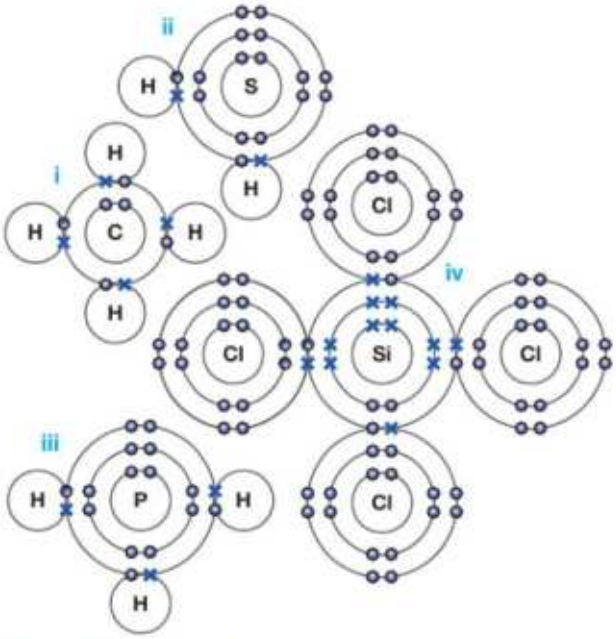
CHAPTER 7

1 ▶

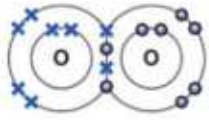
a	MgO	ionic
b	CH_3Br	covalent
c	H_2O_2	covalent
d	$FeCl_2$	ionic
e	NaF	ionic
f	HCN	covalent

2 ▶ a A pair of electrons that is shared between two atoms. The atoms are held together because the nucleus of each is attracted to the shared pair.

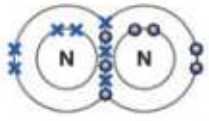
b (It doesn't matter whether students use dots or crosses or just different colours, or what positions (N, S, E, W) the hydrogens occupy in the H_2S or PH_3.)



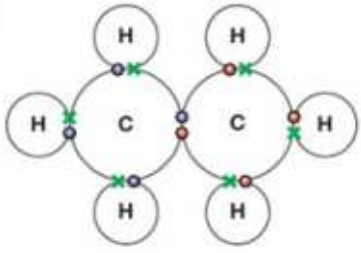
c i



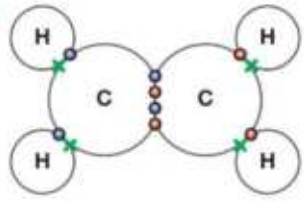
ii



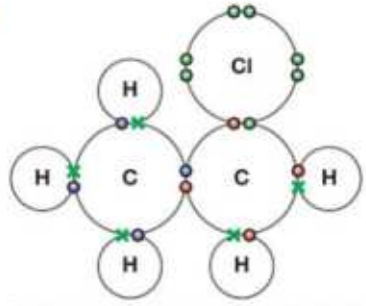
3 ▶ a



b



c



(It doesn't matter what variations of colours or dots and crosses are used. In the chloroethane case, the Cl could equally well have been drawn together with either of the other two hydrogen atoms on the right-hand carbon atom.)

4 ▶ Carbon dioxide has a simple molecular structure; diamond has a giant covalent structure. When carbon dioxide sublimes, only the weak intermolecular forces of attraction must be broken. When diamond sublimes, the strong covalent bonds must be broken. A lot more energy is required to break the strong covalent bonds in diamond than the weak intermolecular forces in carbon dioxide.

5 ▶ a Simple molecular because it is a liquid at room temperature. Only weak intermolecular forces of attraction must be broken to melt solid hexane. Compounds with giant structures have high melting points and boiling points and will be solids at room temperature.

b Pentane has a lower boiling point. The intermolecular forces of attraction are weaker in pentane because the relative formula mass is lower. Weaker intermolecular forces require less energy to break.

c It will not conduct electricity because there are no ions present and all the electrons are held tightly in atoms or covalent bonds.

6 ▶ a To break apart diamond, strong covalent bonds must be broken, which requires a large amount of energy. Much less energy is required to break the weak forces of attraction between the layers in graphite.

b C_{60} fullerene has a molecular structure but graphite has a giant structure. To melt C_{60} fullerene, only weak intermolecular forces must be broken, but to melt graphite strong covalent bonds must be broken. Much less energy is required to break the weak intermolecular forces in C_{60} fullerene than the strong covalent bonds in graphite.

c Each C atom in graphite forms only 3 bonds so there is one electron left over on each atom. These delocalised electrons are free to move throughout the layers.

d All the outer shell electrons in diamond are held tightly in covalent bonds and unable to move around.

7 ▶ (Weakest intermolecular forces of attraction) hydrogen, phosphorus trifluoride, ammonia, ethanol, water, ethanamide (strongest intermolecular forces of attraction).
Higher intermolecular attractions produce higher boiling points – more energy has to be supplied to overcome stronger forces of attraction between molecules.

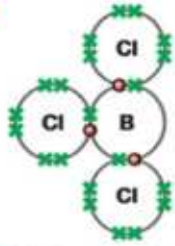
8 ▶ a Nitrogen usually forms 3 bonds because it has 5 electrons in its outer shell. Each N forms 1 bond to F, therefore there must be a double bond between the two N atoms. Formation of a double bond results in each N having 8 electrons in its outer shell.

b



(It doesn't matter what variations of colours or dots and crosses are used. The F atoms could also be drawn in different positions.)

9 ▶ a



b The B atom does not have 8 electrons in its outer shell.

END OF UNIT 1 QUESTIONS

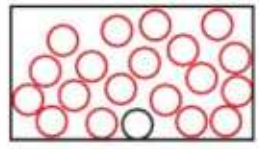
1 ▶ a –255 °C (1)

b



Particles randomly arranged (1) and mostly touching each other (1)

The diagram below would only score 1 mark – for the random arrangement



c number of protons: 1 (1)
number of neutrons: 2 (1)
number of electrons: 1 (1)

d i 2, 5 (1)

ii



three covalent bonds shown, each with a dot and a cross (1)
the remaining 2 electrons on N (1)

e NH_4SO_4 is incorrect (1) because the ammonium ion is NH_4^+ and the sulfate ion is SO_4^{2-}

f fractional distillation (1)

2 ▶ a atomic number (1); groups (1); electrons (1); outer shell (1)

b H (1) and Ar (1)

c i The second property is not a property of metals. Metal oxides are basic (1) and would react with acids rather than with alkalis such as sodium hydroxide. (1)

ii The grey circles represent silicon atoms. (1)
A silicon atom has 4 electrons in its outer shell and will form 4 covalent bonds. (1)
An oxygen atom has 6 electrons in its outer shell and will only form 2 covalent bonds. (1)
(Note: although some of the 'grey atoms' only appear to form 2 bonds this is because only part of the giant structure is shown. None of the 'red atoms' form 4 bonds.)

iii SiO_2 would be a solid at room temperature because it has a giant structure. (1)
A lot of energy is required to break all the strong covalent bonds. (1)

3 ▶ a idea of electron transfer (1)
electron transfer from Sr to Br (1)
the correct number of electrons transferred (1)

b high melting point (1)
strong electrostatic forces of attraction between oppositely-charged ions (1)
require a lot of energy to break (1)

c The relative atomic mass of an element is the weighted average mass of the isotopes of the element. (1)
It is measured on a scale on which a carbon-12 atom has a mass of exactly 12. (1)

d $\frac{50.69 \times 79 + 49.31 \times 81}{100}$ (1)
79.99 (1)

e $Sr(NO_3)_2$ (1)

4 ▶ a Diamond has a giant covalent structure (1), where all the atoms are held together by strong covalent bonds – a lot of energy is required to break these bonds. (1)

b i Graphite has the higher melting point. (1)
Graphite has a giant structure but C_{60} fullerene has a simple molecular structure. (1)
To melt graphite, all the strong covalent bonds between carbon atoms must be broken – this requires a lot of energy. (1)
To melt C_{60} fullerene, only the weak intermolecular forces of attraction must be broken – this requires less energy. (1)

ii Yes, because graphite has delocalised electrons. (1)
Delocalised electrons are free to move (throughout the structure). (1)

iii C_{60} fullerene has a molecular structure rather than a giant structure. (1)
Electrons cannot move between molecules. (1)

5 ▶ a



(1)

b K_2O (1)

c $O=C=O$ (1)

6 ▶ **a** mass of lead = 24.16 – 17.95 = 6.21 g (1)

b mass of oxygen = 24.80 – 24.16 g = 0.64 g (1)

c

	Pb	O	
Combining masses	6.21 g	0.64 g	
No. of moles of atoms	$\frac{6.21}{207} = 0.03$	$\frac{0.64}{16} = 0.04$	(1)
Ratio of moles	3	4	(1)

Empirical formula: Pb_3O_4 (1)

7 ▶ **a** number of moles of copper $= \frac{2.00}{63.5} = 0.0315$ mol (1)

From the chemical equation, the same number of moles of copper(II) nitrate will be produced.

number of moles of $Cu(NO_3)_2$ is 0.0315 mol (1)

M_r of $Cu(NO_3)_2 = 63.5 + 2 \times (14 + 3 \times 16) = 187.5$

mass of $Cu(NO_3)_2 = 187.5 \times 0.0315 = 5.91$ g (1)

b The student would use crystallisation. (1)

Heat the solution in an evaporating basin to drive off some of the water until the solution becomes saturated. (1)

Allow to cool then filter off the crystals that form. (1)

c percentage yield $= \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$

$= \frac{5.23}{7.61} \times 100$ (1)

$= 68.7\%$ (1)

UNIT 2 ANSWERS

CHAPTER 8

1 ▶ They have the same number of electrons in the outer shell (1 electron) and all react in the same way.

2 ▶ **a** A = lithium

b B = potassium; C = hydrogen; D = potassium hydroxide

c $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

d The paper would turn blue / purple.

e Lots of heat is evolved. The melting point of potassium is low.

f E = sodium and F = sodium oxide

sodium + oxygen → sodium oxide

$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

3 ▶ **a** False

b True

c True

d False: the formula of lithium chloride is LiCl

4 ▶ **a** More dense, as density increases down the group.

b 1

c Edexcelium hydroxide and hydrogen

d More reactive than francium, as reactivity increases down the group.

Reactivity increases as the size of the atom increases. An edexcelium atom is larger than a francium atom. The outer electron would be more easily lost from edexcelium – it is less strongly attracted by the nucleus.

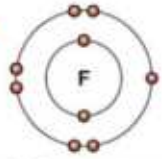
e $2Ed + 2H_2O \rightarrow 2EdOH + H_2$

f Alkaline, because OH^- ions are formed.

g Ed_2O

CHAPTER 9

1 ▶ **a**



b A fluorine atom has 7 electrons in its outer shell – the group number indicates the number of outer shell electrons.

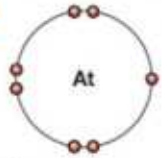
c

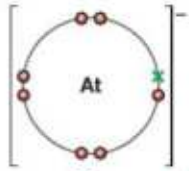


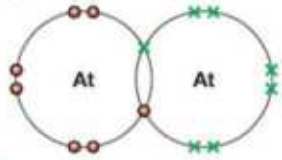
d There are weaker intermolecular forces of attraction between fluorine molecules than between chlorine molecules. Weaker forces require less energy to break. The intermolecular forces are weaker because fluorine has a lower relative molecular mass.

e No reaction because chlorine is less reactive than fluorine and therefore cannot displace it.

2 ▶ **a**







b Astatine would be a solid – melting point increases down the group and iodine is a solid.

c Reactivity decreases down the group so astatine would be less reactive than iodine.

Astatine is a larger atom than iodine and so has a lower attraction for electrons.

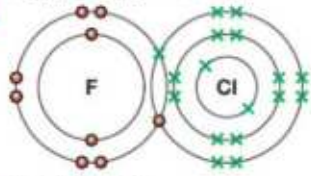
d pH 1–2

e Caesium astatide would be a colourless / white solid because it is an ionic compound. It would probably be soluble in water because many ionic compounds are soluble in water and most of the alkali metal halides are soluble in water (e.g. sodium chloride, potassium iodide etc.).

f $Cl_2(aq) + 2At^-(aq) \rightarrow At_2(s) + 2Cl^-(aq)$
The chlorine is reduced in this reaction because it gains electrons. The At^- is oxidised in the reaction because it loses electrons. Oxidation and reduction both occur, therefore it is a redox reaction.

3 ▶ a $Cl_2(g) + F_2(g) \rightarrow 2ClF(g)$

b



c $F_2 < ClF < Cl_2$
The boiling point increases as the relative molecular mass increases and the strength of the intermolecular forces increases.

d i ClF_3

ii $ClF_3(g) + 2H_2O(l) \rightarrow 3HF(aq) + HCl(aq) + O_2(g)$

CHAPTER 10

1 ▶ a 78.1% **b** 21.0% **c** 0.04% **d** 0.9%

2 ▶ a $95 - 80 = 15\,cm^3$ of oxygen

$\frac{15}{95} \times 100 = 15.8\%$

b The answer is less than expected. The apparatus was not left for long enough; there was not enough time for all the oxygen in the air to react. The experiment could be improved by leaving the apparatus set up for longer.

3 ▶ a The student should follow a procedure such as:
- Weigh a boiling tube.
- Pour 1 g of the metal carbonate into the boiling tube and weigh the boiling tube again.
- Connect a delivery tube to the boiling tube. Connect the other end of the delivery tube to a gas syringe or put in to a measuring cylinder filled with water.
- Heat the boiling tube.
- Allow the apparatus to cool.
- Record the volume of gas collected.
- Re-weigh the boiling tube and contents.

b Carbon dioxide

c $PbCO_3(s) \rightarrow PbO(s) + CO_2(g)$

d Thermal decomposition

e Sodium carbonate is more thermally stable than the other carbonates; it does not decompose when heated.

f The M_r of $PbCO_3$ is 267, whereas the M_r of $CuCO_3$ is 123.5.
1 g of $CuCO_3$ is more moles than 1 g of $PbCO_3$ – more than twice as many moles.
When more moles of solid are heated, more moles of gas will be produced, so a greater volume of gas will be produced.

g The mass goes down because CO_2 is given off. In the first experiment the mass goes down by 0.16 g, which must be the mass of 89 cm^3 of gas.
From the first experiment:
1 cm^3 of gas has a mass of $\frac{0.16}{89} = 0.00180\,g$
100 cm^3 has a mass of $100 \times 0.00180 = 0.180\,g$

h The student did not heat the carbonate for long enough so not all the carbonate decomposed.
Some of the gas escaped / leaked from the apparatus.

4 ▶ Carbon dioxide is one of the gases responsible for the greenhouse effect. These gases absorb IR (infrared) radiation that has been emitted from the Earth's surface. They then re-radiate it in all directions, warming the atmosphere. Heating of the atmosphere could lead to climate change.

CHAPTER 11

1 ▶ a sodium, aluminum, iron, copper

b i magnesium oxide, copper

ii $Mg(s) + CuO(s) \rightarrow MgO(s) + Cu(s)$ *(Include state symbols in all equations for preference.)*

iii Copper(II) oxide (CuO) has been reduced to copper (Cu) because it has lost oxygen – reduction is the loss of oxygen.

iv Copper(II) oxide (CuO) is the oxidising agent because it oxidises the magnesium (gives oxygen to it) and is, in the process, reduced.

c i Zinc is higher in the reactivity series because it takes the oxygen from the cobalt(II) oxide.

ii A reducing agent is a substance which reduces something else. Zinc removes oxygen from the cobalt(II) oxide. Removal of oxygen is reduction.

iii Zinc because it gains oxygen – oxidation is gain of oxygen.

d aluminium, manganese, chromium (Statement 1: Al is above Cr. Statement 2: Mn is below Al. Statement 3: Mn is above Cr. Putting this together gives the final list.)

2 ▶ a oxidised; gain of oxygen

b reduced; loss of oxygen

c oxidised; loss of electrons

d reduced; gain of electrons

3 ▶ Magnesium is above lead because it removes the oxygen from the lead(II) oxide.

4 ▶ a Either: grey iron filings become coated with brown solid. Or: solution fades from blue to colourless (very pale green).

b Iron (Fe) has been oxidised (to Fe^{2+}) because it has lost electrons – oxidation is loss of electrons.

c $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

5 ▶ a nickel, copper, silver

b i Either: colour of solution changes from blue to green. Or: nickel becomes coated with brown solid.

ii $Ni(s) + CuSO_4(aq) \rightarrow NiSO_4(aq) + Cu(s)$

iii $Ni(s) + Cu^{2+}(aq) \rightarrow Ni^{2+}(aq) + Cu(s)$

Nickel has been oxidised by loss of electrons.

6 ▶ a X is between iron and hydrogen in the reactivity series. It displaces hydrogen from dilute hydrochloric acid, and copper from copper(II) sulfate, so it must be above hydrogen and copper. It won't displace iron from iron(II) sulfate, so it must be below iron.

b i yes: X nitrate and silver

ii no reaction

iii no reaction (at least, not in the short term)

iv yes: X chloride and copper

v yes: X sulfate and hydrogen

7 ▶ a hydrogen

b aluminium chloride

c $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$

d Aluminium is covered by a very thin, but very strong, layer of aluminium oxide which prevents the acid getting at the aluminium underneath. On heating, the acid reacts with the oxide and removes it. The aluminium then shows its true reactivity, and produces a vigorous reaction.

8 ▶ Drop a very small piece into cold water. If it reacts, judge its reactivity relative to K, Na, Ca or Mg.

If it doesn't react, add a small piece to dilute hydrochloric acid and warm if necessary. Rapid reaction in the cold acid would place it as 'similar to magnesium'. A few bubbles of hydrogen in the cold acid, and more on heating would place it as 'similar to iron or zinc'.

If there is no reaction, then it is 'below hydrogen'.

9 ▶ a The iron / steel must be exposed to oxygen (air) and water.

b Painting prevents oxygen and water from coming into contact with the iron / steel.

c It is iron / steel coated with zinc.

d It will take much longer for the car to rust. Zinc is more reactive than iron and so corrodes in preference to the iron. The zinc prevents the iron rusting even if the coating is scratched. In the past, if the paint was scratched, the steel underneath would rust. This does not happen if the car is made of galvanised steel, so the life of the car is extended.

10 ▶ a

	Pearsonium chloride solution	Mollium chloride solution	Rosium chloride solution	Amelium chloride solution
pearsonium	✗	✗	✗	✗
mollium	✓	✗	✓	✓
rosium	✓	✗	✗	✗
amelium	✓	✗	✓	✗

b mollium > amelium > rosium > pearsonium

c mollium + pearsonium chloride → mollium chloride + pearsonium

CHAPTER 12

1 ▶

	methyl orange	phenolphthalein	litmus
a	yellow	pink	blue
b	red	colourless	red

2 ▶

solution	pH	strongly acidic	weakly acidic	neutral	weakly alkaline	strongly alkaline
potassium iodide	7			✓		
propanoic acid	4.2		✓			
sodium carbonate	9.5				✓	
potassium hydroxide	13					✓
iron(III) chloride	2.4	✓				
nitric acid	1.3	✓				

3 ▶ a $Na_2O + 2HNO_3 \rightarrow 2NaNO_3 + H_2O$

b $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$

4 ▶ Neutralisation – reaction a) involves an acid reacting with a base (sodium oxide) and reaction b) involves an acid reacting with an alkali (KOH).

CHAPTER 13

1 ▶ a copper(II) oxide, copper(II) hydroxide, copper(II) carbonate

b $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$
$Cu(OH)_2(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + 2H_2O(l)$
$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$

2 ▶ a A = copper; B = copper(II) oxide; C = copper(II) sulfate; D = copper(II) carbonate; E = carbon dioxide; F = copper(II) nitrate

b i $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

ii $CuCO_3(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + CO_2(g) + H_2O(l)$

3 ▶ a i Description could include: silvery metal; colourless acid; slow bubbles of gas on warming; formation of green solution; possible disappearance of nickel if very small quantities were used.

Testing for gas: pops with lighted splint held to mouth of tube.

ii hydrogen

iii $Ni(s) + H_2SO_4(aq) \rightarrow NiSO_4(aq) + H_2(g)$

b i Description could include: green solid; colourless acid; bubbles of gas produced in the cold acid; formation of green solution; green powder disappears if excess acid is used.

Testing for gas: bubble through limewater to give a white precipitate (milky, cloudy).

ii $NiCO_3(s) + 2HCl(aq) \rightarrow NiCl_2(aq) + CO_2(g) + H_2O(l)$

4 ▶

soluble	insoluble
sodium chloride	lead(II) sulfate
zinc nitrate	calcium carbonate
iron(III) sulfate	lead(II) chloride
potassium sulfate	copper(II) carbonate
aluminium nitrate	silver chloride
ammonium chloride	barium sulfate
magnesium nitrate	calcium sulfate (almost insoluble)
sodium phosphate	nickel(II) carbonate
potassium dichromate(VI)	chromium(III) hydroxide

5 ▶ a Dilute sulfuric acid in a beaker / flask. Heat gently. Add copper(II) oxide a little at a time until no more reacts. Filter into an evaporating basin. Evaporate gently until a sample will crystallise on cooling. Leave to crystallise. Separate and dry crystals.

b i $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

ii $CuSO_4(aq) + 5H_2O(l) \rightarrow CuSO_4.5H_2O(s)$

6 ▶

	acid	base
a	H_3O^+	CO_3^{2-}
b	H_2SO_4	MgO
c	HNO_3	NH_3
d	H_2SO_4	H_2O
e	HCl	NH_3
f	CH_3COOH	NH_3

CHAPTER 14

1 ▶ a chlorine **b** ammonia **c** carbon dioxide **d** hydrogen **e** oxygen

2 ▶ a Clean a nichrome or platinum wire by dipping it into concentrated hydrochloric acid and then holding it in a flame until no colour shows. Moisten the wire with concentrated hydrochloric acid, dip it into the solid, and then hold it in the flame. Lithium ions give a red flame colour.

b Warm the solid very gently with sodium hydroxide solution. Test any gases given off with a piece of damp red litmus paper. If it turns blue, ammonia is being given off from an ammonium compound.

c Make a solution in pure water. Add dilute hydrochloric acid + barium chloride solution. A white precipitate shows the presence of sulfate ions.

d Add dilute hydrochloric acid or dilute nitric acid. (Not sulfuric acid – this will form an insoluble layer of calcium sulfate around the calcium carbonate, stopping the reaction.) Look for a colourless odourless gas which turns limewater milky.

e Make a solution in pure water. Add dilute nitric acid + silver nitrate solution. A yellow precipitate shows the presence of iodide ions.

3 ▶ a A = iron(III) chloride; B = iron(III) hydroxide; C = silver chloride

b B: $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$
or: $FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$
C: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
or $3AgNO_3(aq) + FeCl_3(aq) \rightarrow 3AgCl(s) + Fe(NO_3)_3(aq)$

4 ▶ a D = iron(II) sulfate; E = iron(II) hydroxide; F = barium sulfate

b E: $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$
or: $FeSO_4(aq) + 2NaOH(aq) \rightarrow Fe(OH)_2(s) + Na_2SO_4(aq)$
F: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
or $BaCl_2(aq) + MgSO_4(aq) \rightarrow BaSO_4(s) + MgCl_2(aq)$

5 ▶ a G = potassium carbonate; H = potassium nitrate; I = carbon dioxide *(Note: G could also be potassium hydrogencarbonate, but, because hydrogencarbonates haven't been covered in the course, a student is unlikely to come up with it.)*

b $CO_3^{2-}(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$
or: $K_2CO_3(s) + 2HNO_3(aq) \rightarrow 2KNO_3(aq) + CO_2(g) + H_2O(l)$

6 ▶ a J = ammonium bromide; K = ammonia; L = silver bromide

b $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

7 ▶ a Dissolve the mixture in the minimum possible amount of hot water and then allow it to cool again. The small amount of the more soluble potassium carbonate will stay in solution, but crystals of potassium nitrate will be formed on cooling. Filter these off, and wash them on the filter paper with a small amount of very cold water. Allow them to dry.

b Take a sample and add any named dilute acid. If the crystals are free of potassium carbonate, there won't be any fizzing.

8 ▶ a Add a few drops of the liquid to some anhydrous copper(II) sulfate. If the colour changes from white to blue then water is present.

b Measure the boiling point of the liquid. If the liquid boils at 100 °C it is pure water. The freezing / melting point can also be measured – pure water freezes / melts at 0 °C.

c The test-tube becoming warm indicates that an exothermic reaction has occurred. An exothermic reaction with sodium hydroxide solution could mean that the colourless liquid is an acid – neutralisation reactions are exothermic. The fact that there is no other visible reaction indicates that there is no metal present that has an insoluble hydroxide.

The second test indicates that the solution does not contain carbonate ions – carbonate ions would produce fizzing with dilute hydrochloric acid.

The third test indicates that no sulfate ions are present – the solution cannot be sulfuric acid.

The last test indicates the presence of chloride ions. With the results of the other tests, this suggests that the solution is dilute hydrochloric acid.

The student could confirm this by adding an indicator, to see whether the liquid is acidic.

END OF UNIT 2 QUESTIONS

1 ▶ a They all have 1 electron in the outer shell. (1)

b Potassium oxide (1)

c The piece of lithium floats (1); hydrogen gas is formed (1); the final solution is alkaline (1)

d i It forms a 1+ ion in compounds (1); it reacts with water and air (1)

ii The density increases from lithium to sodium but decreases from sodium to potassium. (1)

The trend is not clear for the whole group. (1)

2 ▶ a Because there will be no reaction (1):

a halogen cannot react with its halide ion / chlorine cannot react with chloride ions / bromine cannot react with bromide ions / iodine cannot react with iodide ions (1).

b

	potassium chloride solution	**potassium bromide solution**	**potassium iodide solution**
chlorine solution		orange solution formed	brown solution formed
bromine solution	no reaction		brown solution formed
iodine solution	no reaction	no reaction	

(1 mark for each correct cell)

c chlorine + potassium bromide → potassium chloride + bromine (1)

d $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

$Cl^-(aq)$ (1)

$Br_2(aq)$ (1)

balancing (1)

e Chlorine gains electrons to form chloride ions. (1)

Bromide ions lose electrons to form bromine. (1)

Gain of electrons is reduction and loss of electrons is oxidation. (1)

f i 5 (1)

ii Test: damp litmus paper / universal indicator paper (1)

Positive result: the paper is bleached (goes white) (1)

iii Test: add dilute nitric acid (1) followed by silver nitrate solution (1)

Positive result: white precipitate (1)

3 ▶ a nitrogen (1)

b i The oxygen in the air is used up as it reacts with the iron. (1)

Water is pushed in by the atmosphere to take its place / the pressure in the measuring cylinder is reduced. (1)

ii All the oxygen has reacted and so there is nothing to react with the iron. (1)

iii Hydrated iron(III) oxide (1)

iv There is no oxygen present (1); oxygen is required for the splint to burn. (1)

v The total amount of oxygen present in the original sample of air is 94 – 75 = 19 cm^3 of oxygen. (1)

9 cm^3 of oxygen is used up after one day, therefore there is 19 – 9 = 10 cm^3 of oxygen still present after one day. (1)

This is in a total volume of 85 cm^3 (1) (reading on the measuring cylinder).

Percentage oxygen = $\frac{10}{85} \times 100 = 11.8\%$ (1)

vi These will produce hydrogen when they react with the water present. (1)

Hydrogen gas will take up space in the measuring cylinder, so the volume change will not show the volume of oxygen used up. (1)

vii Suggest one change that the student could make to the *apparatus* so he does not have to wait so long for the results. (1)

Use more iron filings / more finely-divided (higher surface area) iron filings / warm the apparatus. (1)

c i blue (1)

ii $S + O_2 \rightarrow SO_2$ (1)

iii The litmus solution will be red. (1)

Non-metal oxides are acidic and dissolve in water (if soluble, like SO_2) to form acidic solutions. (1)

d i $4Na + O_2 \rightarrow 2Na_2O$

all formulae (1)

balancing (1)

ii hydroxide ion (1)

4 ▶ a Put dilute sulfuric acid into a beaker and heat it on a tripod and gauze using a Bunsen burner. (1)

Add excess copper(II) oxide. (1)

Filter off the excess copper(II) oxide. (1)

b Test: add hydrochloric acid followed by barium chloride solution (1)

Positive result: white precipitate (1)

c copper(II) hydroxide (1)

d i Any two from:

Concentration of copper(II) sulfate (1)

Volume of copper(II) sulfate solution (1)

How finely divided the metal is (1) *(if the metal is very finely divided it will react more quickly and the heat will be given out more quickly, so there is less chance for heat to be lost to the surroundings. This will give a more accurate value for the temperature change)*

ii Zinc > nickel > silver (1)

iii The temperature rise would be zero. (1)

Copper will not react with copper(II) sulfate / copper ions. (1)

iv The mass of 1 mole of zinc (65 g) is very similar to the mass of 1 mole of nickel (59 g). (1)

Because the student used the same mass of each metal, the number of moles of nickel and zinc is very similar. (1)

Because silver does not react it does not matter how much the student uses. (1)

v Nickel is oxidised. (1)
Ni loses electrons to form Ni^{2+} and oxidation is loss of electrons. (1)

e Heat the solution to drive off the water and form (small) crystals of hydrated copper(II) sulfate. (1)
Keep heating the solid. (1)

f i Dip a piece of (nichrome) wire into concentrated hydrochloric acid and then into the solid. (1)
Hold the wire in the blue / roaring / non-luminous flame of a Bunsen burner. (1)

ii blue-green (1)

5 ▶ a 
Dot and cross in the covalent bond (1)
All other electrons (1)

b A proton / hydrogen ion / H^+ is transferred from the HCl to the water. (1)
HCl is an acid because it donates a proton / hydrogen ion / H^+. (1)
H_2O is a base because it accepts a proton / hydrogen ion / H^+. (1)

c i A white precipitate would form. (1)

ii Hydrochloric acid contains chloride ions (1) so it will always give a positive test for chloride ions. (1)

d $CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$
reactants (1)
products (1)
balancing (1)

6 ▶ a iron(II) (1) chloride (1)

b B = iron(II) hydroxide (1) $Fe(OH)_2$ (1)

c D = iron(III) hydroxide (1) $Fe(OH)_3$ (1)

d redox (1)
The iron(II) is oxidised to iron(III). (1)

UNIT 3 ANSWERS

CHAPTER 15

1 ▶ A reaction in which heat energy is given out to the surroundings.

Correctly balanced equations for any two exothermic reactions e.g. any combustion reactions (metals, hydrogen, hydrocarbons, etc. in oxygen), neutralisation reactions involving metal soxides or hydroxides and acids, magnesium and acids. For example, $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ or $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

2 ▶ A reaction in which heat energy is absorbed from the surroundings.

3 ▶ a exothermic b exothermic c endothermic
d exothermic e endothermic f exothermic

4 ▶ The cans have two chambers. The outer chamber contains the beverage or food to be heated. The inner chamber contains calcium oxide and water. The calcium oxide and water are kept separate by a seal. Pushing a button on the bottom of the can breaks the seal and allows the calcium oxide and water to come into contact. The following exothermic reaction takes place:
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

5 ▶ a Her first two results weren't reliable. There was too much difference between them.

b Any two from: wear a lab coat; avoid touching the hot copper can; tie long hair back.

c Heat energy change = $Q = mc\Delta T$
Mass of water being heated = m = 100 g
c is the specific heat capacity of the water
c = 4.18 J/g/°C
Temperature change of water = ΔT = 55.0 – 19.0 = 36.0 °C
Heat evolved = $Q = mc\Delta T$ = 100 × 4.18 × 36.0 J = 15048 J = 15.0 kJ to 3 significant figures

d Mass of hexane burnt = 35.62 – 35.23 g = 0.39 g
Heat evolved per gram = $\frac{15.048}{0.39}$ = 38.6 kJ/g to 3 significant figures
The combustion reaction is exothermic, therefore heat energy released per gram = –38.6 kJ/g

e Number of moles of hexane, C_6H_{14}, burnt =
$n = \frac{\text{mass } (m)}{\text{relative molecular mass } (M_r)} = \frac{0.39}{86} = 0.00453 \text{ mol}$
The molar enthalpy change of combustion of hexane (ΔH)
$= \frac{\text{heat energy change } (Q)}{\text{number of moles of ethanol burned } (n)}$
$= \frac{15.048}{0.00453} = 3320 \text{ kJ/mol}$ to 3 significant figures
The combustion reaction is exothermic, therefore ΔH = –3320 kJ/mol

f Any two from: misreading one of the weighings of the spirit burner so that it looked as if less hexane had been burnt than was really the case; misreading the thermometer to give a final temperature higher than it should have been; adding less than 100 cm^3 of water to the flask, so that the temperature went up more than it should because the heat was going into a smaller volume of water.

g Any two from: heat loss to the surroundings; heat is lost to warm up the copper calorimeter or the thermometer; incomplete combustion of the fuel.

6 ▶ a Heat energy change = $Q = mc\Delta T$
Mass of solution being heated = m = 50 g (the mass of the lithium chloride is relatively small and it is ignored in the calculation)
c is the specific heat capacity of the diluted solution of lithium chloride, which we assume to be the same as the heat capacity of water: c = 4.18 J/g/°C
Temperature change of water = ΔT = 33.5 – 17.0 = 16.5 °C

Heat evolved = $Q = mc\Delta T = 50 \times 4.18 \times 16.5\,J = 3448.5\,J = 3.45\,kJ$ to 3 significant figures

b Number of moles of lithium chloride dissolved =

$$n = \frac{\text{mass } (m)}{\text{relative formula mass } (M_r)} = \frac{5.15}{42.5} = 0.121 \text{ mol}$$

c The enthalpy change of solution

$$\Delta H = \frac{\text{heat energy change } (Q)}{\text{number of moles of lithium chloride dissolved } (n)}$$

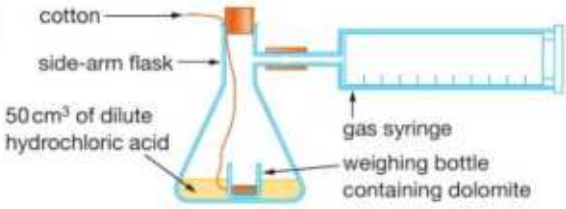
$$= \frac{3.45}{0.121} = 28.5\,kJ/mol \text{ to 3 significant figures}$$

The dissolving of lithium chloride is exothermic, so $\Delta H = -28.5\,kJ/mol$

d Any two from: heat loss to the surroundings; heat is lost to warm up the solution container or the thermometer; incomplete transfer of the salt from the weighing boat into the water; some salt does not dissolve completely in water.

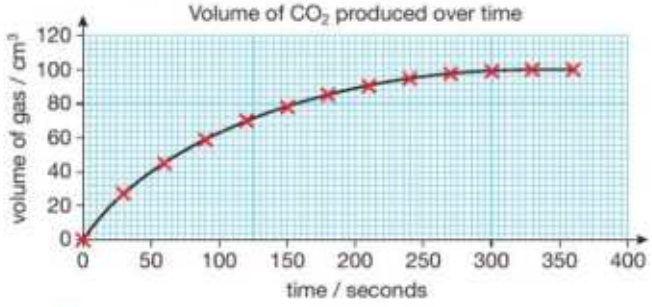
CHAPTER 16

1 ▶ a



Collection of gas over water into an inverted measuring cylinder is an acceptable alternative. Pieces of dolomite in a weighing bottle are put into the conical flask before the reaction starts. This is to make sure that the reaction can be started without losing any carbon dioxide.

b Graph should be completely smooth with the axes properly labelled.



c At the very beginning of the reaction. The reaction can only happen when acid particles collide with the solid dolomite. Numbers of acid particles per unit volume are greatest at the beginning of the reaction before any are used up. Therefore the greatest number of collisions per second and the fastest reaction are at the beginning.

d 70 seconds (read this off the graph; allow some tolerance depending on the size of graph paper available)

e Volume produced within the first 80 seconds = 55 cm

(The average rate = $\frac{55}{80} = 0.688\,cm^3/s$ to 3 significant figures)

f i There would be a lower initial rate; same volume of gas.

ii There would be a lower initial rate; half the volume of gas (50 cm^3).

iii The initial rate would be the same; half the volume of gas (50 cm^3). (The initial rate depends on the original concentration of the acid, which is the same.)

iv The initial rate would be faster; same volume of gas.

2 ▶ a The time taken for the reaction will increase. A reaction happens when acid particles collide with the magnesium. If the concentration of acid is reduced, there will be fewer acid particles per unit volume. This means there will be fewer collisions per second, and therefore a slower reaction.

b The time taken for the reaction will decrease. The acid particles will be moving faster, so they will collide with the magnesium more often. The reaction only happens if the energy of the collision equals or exceeds the activation energy. At higher temperatures more acid particles will have energy greater than or equal to the activation energy, so a greater proportion of the collisions will be successful.

c Answers could include: Acid will be used up quickly immediately around the magnesium – stirring brings fresh acid into contact with it; bubbles of hydrogen form around the magnesium, preventing acid from reaching it – stirring helps to dislodge the bubbles; bubbles of hydrogen lift the magnesium to the surface (sometimes above the surface) of the acid, lowering contact between acid and magnesium – stirring helps to prevent this.

3 ▶ a Reactions only happen if collisions have energies equalling or exceeding activation energy. Catalysts provide an alternative route for the reaction with a lower activation energy. More particles now have energy greater than or equal to the activation energy, so there will be more successful collisions per unit time.

b To find out whether it speeds the reaction up: Place equal volumes of the same hydrogen peroxide solution in two test-tubes side-by-side. Add some iron(III) oxide to one test-tube and see if bubbles are produced more quickly in that tube.

To show that it is unchanged: Use a known mass of iron(III) oxide. When the reaction stops, filter the mixture through previously weighed filter paper, allow to dry, and re-weigh. Show that the mass of iron(III) oxide is unchanged. (If the mass has changed, and you haven't lost any during the separation process, the iron(III) oxide must have reacted in some way.)

4 ▶ a The reversible symbol '⇌' shows that the reaction can go both ways. The reactants can react to form the products and the products can react to form the reactants.

b White solid decomposes to form colourless gases.

END OF UNIT 3 QUESTIONS

1 ▶ a i 19.3 (1), 16.6 (1), 2.7 (1)

ii A (1)

b i $Q = mc\Delta T = 100.0 \times 4.2 \times (23.2 - 15.9) = 3.066\,\text{kJ}$
calculation of temperature change (1)
using the correct mass (100 g, award mark if 105 g is used) (1)
correct answer for Q (1)

ii $n = \frac{\text{mass of calcium chloride}}{M_r} = \frac{5}{(40 + 35.5 * 2)}$
$= \frac{5}{111} = 0.0450\,\text{mol}$ to 3 significant figures
calculation of M_r (1)
correct answer to 2–4 significant figures (1)

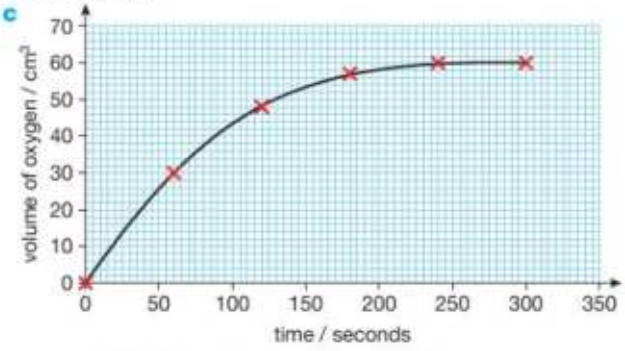
iii $\Delta H = \frac{3.066}{0.0450} = 68.1\,\text{kJ/mol}$ to 3 significant figures
The molar enthalpy change is –68.1 kJ/mol as the dissolving is exothermic.
dividing Q by n (1)
correct answer (must have a negative sign) (1)

c Heat loss to the surrounding air through beaker (1)
Some magnesium chloride is left on the weighing boat / did not dissolve in water completely (1)

2 ▶ a $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$
correct formulae of reactants and products (1)
correct balancing (1)

b To prevent the loss of oxygen at the beginning of the reaction (1)

c



correct labelling of axes with units (1)
correct points plotted (2)
a smooth curve of best fit, going through all of the points (1)

d i 125 seconds

ii $43\,\text{cm}^3$

iii $\frac{53}{150} = 0.353\,\text{cm}^3/\text{sec}$
correct numerical answer (1)
correct unit (1)

e The reaction has stopped (1) because all the hydrogen peroxide has been used up (1).

f i B (1)

ii Weigh a sample of manganese(IV) oxide and add to hydrogen peroxide (1). Oxygen is produced at a faster rate with manganese(IV) oxide than without (1). Filter the reaction mixture and dry the solid (1). Re-weigh the solid and the mass should be the same as before if it acts as a catalyst (1).

g Shallower curve than the original (1) but the end volume remains the same (1)

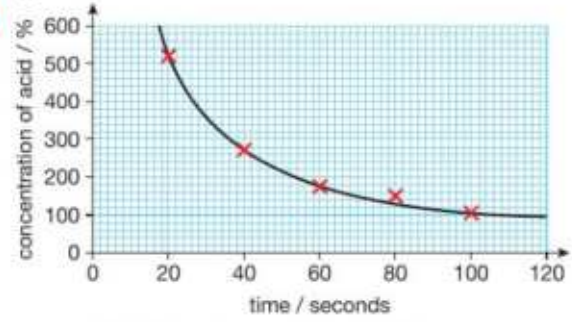
h Shallower curve than the original (1) and only $30\,\text{cm}^3$ (half the volume) of gas is produced (1)

3 ▶ a The mass (1) and the surface area / size (1)

b To let the gas escape but keep the liquid inside the conical flask (1)

c i B

ii



correct labelling of axes with units (1)
correct points plotted (2)
a smooth curve of best fit, going through all but one point (1)

iii 150 seconds

iv C

d i The mass of CO_2 given off is directly (1) proportional (1) to the concentration of the acid.

ii Increasing the concentration of the acid increases the rate of reaction. (1) This is because there are more acid particles within a fixed volume (1) so the frequency of successful collisions between the acid and the marble chips increases (1).

4 ▶ a i The gas particles have more kinetic energy (1) so more particles have energy greater than or equal to the activation energy (1). There are more successful collisions per unit time (1).

ii The rate will increase (1) as gas particles are closer together so there are more frequent collisions (or more successful collisions per unit time) (1).

iii Reactions happen on the surface of the catalyst (1) and gauzes have greater surface area (1).

b The catalyst increases the rate of the reaction without itself being used up (1). It saves money which would be spent on increasing temperature or pressure (1).

5 ▶ a reversible reaction (1), enthalpy change (1)

b The forward reaction is endothermic. (1)

c The reaction mixture becomes more brown in colour. (1)

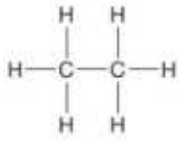
UNIT 4 ANSWERS

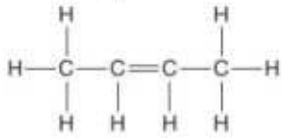
CHAPTER 17

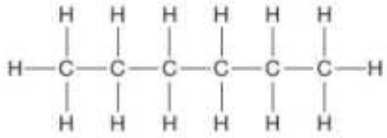
1 ▶ a i methane

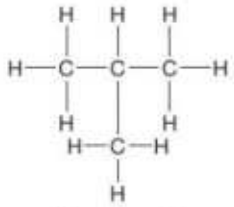
ii propane

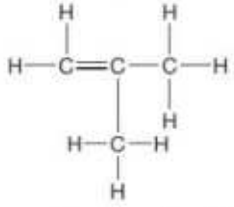
iii hexane
iv propene
v ethene
vi but-1-ene

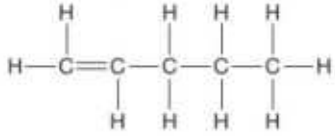
b i 

ii 

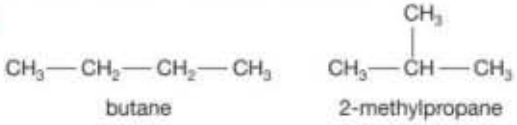
iii 

iv 

v 

vi 

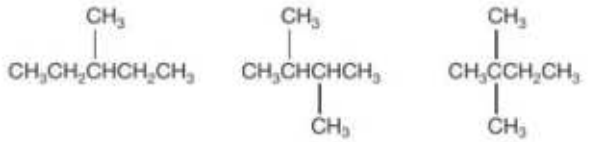
2 ▶ a The existence of molecules with the same molecular formula but different structural formulae.

b 

(In these and subsequent formulae, if you aren't asked specifically for displayed formulae, these quicker forms are acceptable.)

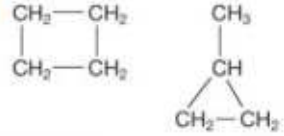
c $CH_3CH_2CH_2CH_2CH_2CH_3$ $CH_3CHCH_2CH_2CH_3$ (CH_3 branch)

hexane — 2-methylpentane



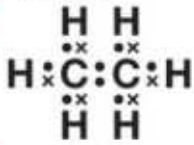
d $CH_3CH_2CH{=}CH_2$ $CH_3CH{=}CHCH_3$ $CH_3C(CH_3){=}CH_2$

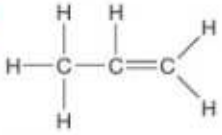
but-1-ene — but-2-ene — (2-methylpropene)

e 

3 ▶ a addition
b combustion
c addition
d substitution
e substitution

4 ▶ a C: it contains an element other than carbon and hydrogen.

b 

c 

d C_nH_{2n+2}

e Same functional group / similar chemical properties; show a gradation in physical properties; each member differs from the next by a $-CH_2-$

f $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

CHAPTER 18

1 ▶ a Carbon and hydrogen

b The crude oil (mixture of hydrocarbons) is heated until it boils. The vapour passes into a fractionating column. The temperature is higher at the bottom of the column than at the top. Different fractions condense and are drawn off at different heights in the column. The hydrocarbons with the highest boiling points (longer chains) condense towards the bottom of the column. The smaller hydrocarbon molecules travel further up the column until they condense and are drawn off.

c Gasoline – petrol for cars; diesel – fuel for lorries or buses

d Any two from: refinery gas, kerosene, fuel oil or bitumen

e The average size of the molecules in gasoline is smaller than in diesel. Diesel is darker in colour and more viscous than gasoline.

f Any between $n = 5 - 10$ for C_nH_{2n+2}

g i $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

ii Carbon monoxide is poisonous as it reduces the blood's ability to carry oxygen around the body.

2 ▶ a The sulfur (or sulfur compound) burns to make sulfur dioxide. The sulfur dioxide reacts with water and oxygen in the atmosphere to produce sulfuric acid that falls as acid rain.

b The spark in the engine causes nitrogen to react with oxygen to produce various oxides of nitrogen.

c Sulfur dioxide reacts with water and oxygen in the atmosphere to produce sulfuric acid. The sulfuric acid in acid rain can react with calcium carbonate and corrode the buildings.

3 ▶ a Crude oil produces too many larger hydrocarbons / not enough of the more useful smaller ones. Smaller alkanes can be used as fuel for cars. Cracking also produces alkenes that can be used to make polymers.

b Heat the vaporised fraction in the presence of a silicon dioxide or aluminium oxide catalyst at 600–700 °C.

c $C_{11}H_{24} \rightarrow 2C_2H_4 + C_7H_{16}$

d Any other valid cracking equation starting with $C_{11}H_{24}$. For example:

$C_{11}H_{24} \rightarrow C_2H_4 + C_9H_{20}$

or $C_{11}H_{24} \rightarrow C_2H_4 + C_3H_6 + C_6H_{14}$

or lots of other variants. In each case, at least one hydrocarbon should be an alkane (C_nH_{2n+2}), and at least one an alkene (C_nH_{2n}).

4 ▶ This is entirely open to your imagination and ability to think both logically and laterally. It is impossible to suggest 'right' answers.

CHAPTER 19

1 ▶ a Saturated hydrocarbons contain only C–C single bonds and have no double or triple bonds.

b i $C_{11}H_{24}$

ii Liquid

iii $C_{11}H_{24}(l) + 17O_2(g) \rightarrow 11CO_2(g) + 12H_2O(l)$

iv $2C_{11}H_{24} + 23O_2 \rightarrow 22CO + 24H_2O$

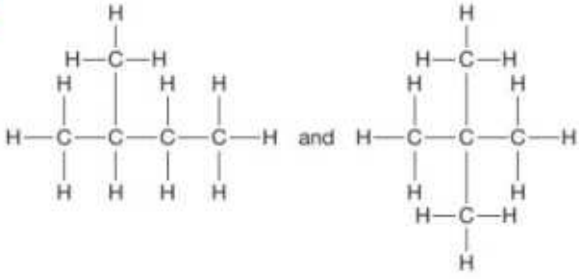
Carbon monoxide is poisonous, as it reduces the ability of the blood to carry oxygen around the body.

2 ▶ a C_5H_{12}

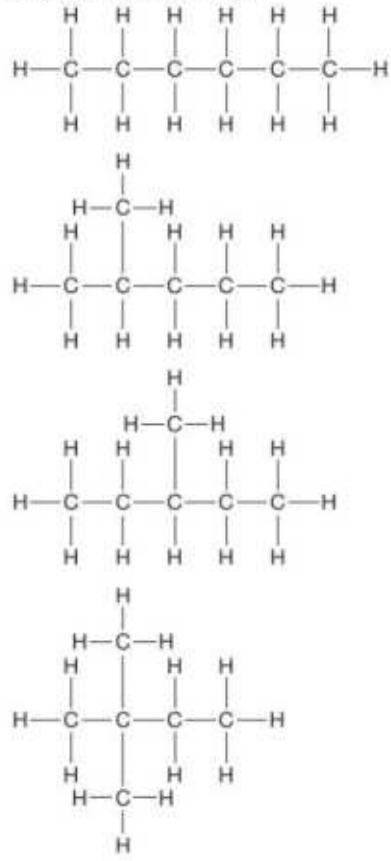
b C_4H_{10}

c C_6H_{14}

3 ▶ a



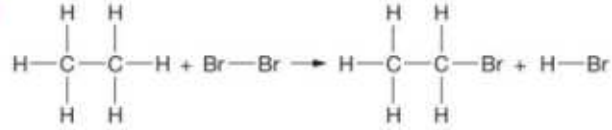
b Any 2 of the following:



4 ▶ a UV light

b Substitution

c



(1-)bromoethane

5 ▶ a $C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$

b $CH_3CH_2CH_2CH_2Cl$ 1-chlorobutane $CH_3CH(Cl)CH_2CH_3$ 2-chlorobutane

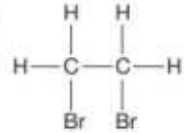
CHAPTER 20

1 ▶ a i Any two from: same general formula; same functional group or similar chemical properties; show a gradation in physical properties; each member differs from the next by a $-CH_2-$.

ii Unsaturated compounds contain one or more carbon–carbon double or triple bonds.

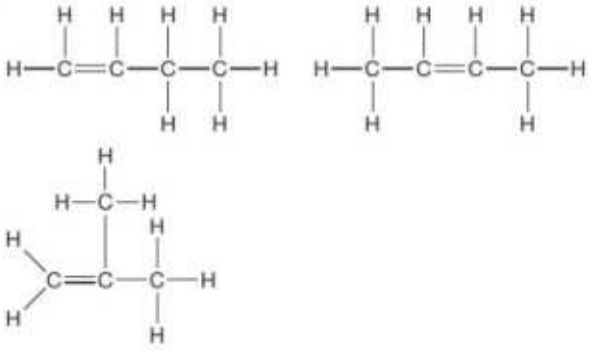
b i Starting: orange; Finishing: colourless

ii

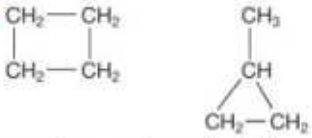


1,2-dibromoethane

c

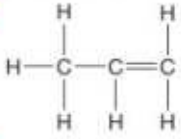


d

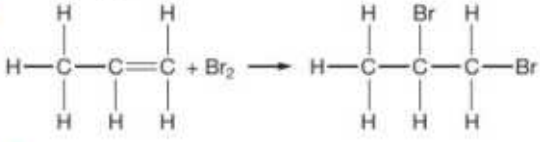


2 ▶ a a carbon–carbon double bond

b



c



d i $CH_3CH_3 + Br_2(g) \rightarrow CH_3CH_2Br + HBr(g)$

ii In this (substitution) reaction, one of the hydrogens has been replaced by a bromine during the reaction. In the previous (addition) reaction, nothing was lost when the two molecules combined together.

3 ▶ a 1,2-dichloropropane: $CH_2ClCHClCH_3$

b ethane: CH_3CH_3

4 ▶ a Cracking

Conditions: 1) The presence of a silicon dioxide (silica) or aluminium oxide (alumina) catalyst. 2) Heat the vaporised alkanes at high temperatures of 600–700 °C.

b Test: shake with bromine water

Result with propane: no colour change (solution remains orange)

Result with propene: solution changes colour from orange to colourless

5 ▶ a $CH_3CH_2CH_2CH_2OH$ (butan-1-ol) or $CH_3CH_2CH(OH)CH_3$ (butan-2-ol)

b $CH_3CH_2CH_2CH_2Cl$ (1-chlorobutane) or $CH_3CH_2CHClCH_3$ (2-chlorobutane)

c $CH_3CH_2CHBrCH_2Br$ (1,2-dibromobutane)

CHAPTER 21

1 ▶ a Unsaturated: containing one or more carbon–carbon double or triple bonds.

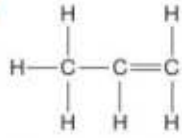
Hydrocarbon: compound containing carbon and hydrogen only

b $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

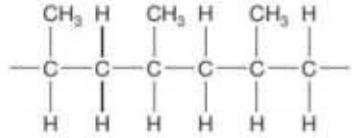
c Ethene can be used to make addition polymer polyethene, which is used for making plastic bags, milk bottles etc.

2 ▶ a Joining up lots of little molecules (monomers) to make one big molecule (a polymer).

b

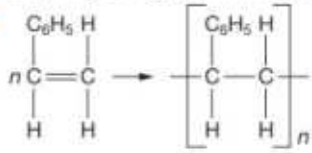


c The 'continuation' bonds at each end are an important part of this structure. Marks will be lost in an exam if they are omitted.

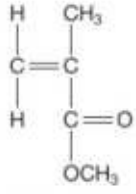


d Joining two or more molecules together without anything being lost in the process.

e



f Drawing the molecule to show its relationship with the structure of the polymer as drawn in the question:



g Either: buried in landfill sites because there is no emission of poisonous carbon monoxide or no carbon dioxide to contribute to global warming or no sulfur dioxide to contribute to acid rain. Or: incineration because no space is filled up in landfills or energy can be generated to provide heat for office buildings.

END OF UNIT 4 QUESTIONS

1 ▶ a D (1)

b Used as liquefied petroleum gas / domestic heating or cooking (1)

c Gasoline (1)

d Crude oil is separate into fractions by fractional distillation. (1)

It is heated until it boils and the vapour enters a fractionating column (1), which is cooler at the top and hotter at the bottom (1). The fractions with a lower boiling point condense nearer to the top of the column and can be tapped off / the fractions with a higher boiling point condense nearer to the bottom of the column and can be tapped off (1).

e As the number of carbon atoms increase, the boiling point of a hydrocarbon increases. (1)

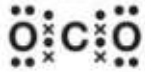
This is because the intermolecular forces increase as the number of carbon atoms increases, so it takes more energy to break them during boiling. (1)

f $2C_{15}H_{32} + 31O_2 \rightarrow 30CO + 32H_2O$

correct formulae of products (1)

correct balancing of the equation (1)

g i



ii B

h i 600–700 °C (1); silica / alumina as a catalyst, accept 'aluminium oxide / silicon dioxide / aluminosilicate / zeolite or the correct formulae (1)

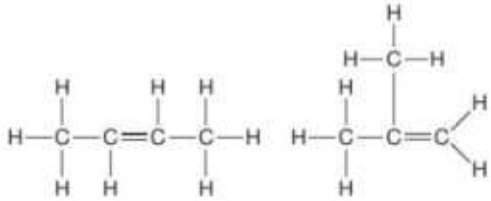
ii To make more of the smaller-chain fractions, for example, gasoline to use as petrol (1)

To produce more alkenes that can be used for making polymers (plastics) (1)

iii C_9H_{20} (1)

iv The compound contains one or more carbon–carbon double or triple bonds (1)

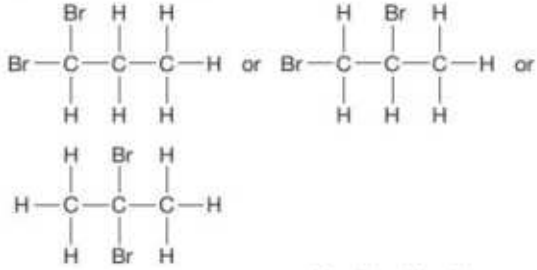
v



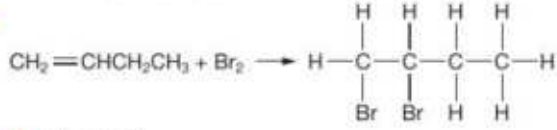
2 ▶ a E contains an element that is not carbon or hydrogen. (1)

b i 1,3-dibromopropane (1 mark for dibromopropane)

ii



c



d i B and D

ii C_nH_{2n+2}

iii Any two from:

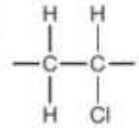
Same functional group / same or similar chemical properties (1)

Show a trend in physical properties (1)

Each member differs from the next by a $-CH_2-$ unit (1)

e i Poly(chloroethene) or polyvinylchloride (1)

ii



iii Any two from:

They are inert. (1)

They are non-biodegradable. (1)

If they are burned, they release toxic gases including carbon monoxide or hydrogen chloride. (1)

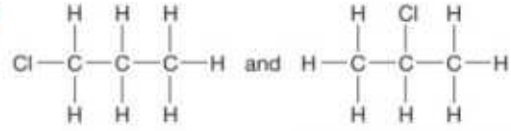
iv No colour change / bromine water remains orange (1)

Polymer of compound A is saturated / contains no C=C bond (1)

f i UV light (1)

ii Substitution (1)

iii



3 ▶ a

	C	H	O
Mass (in 100 g)	55	9	36
A_r	12	1	16
Number of moles	4.58	9	2.25
Smallest number of moles	2.25	2.25	2.25
Ratio	2	4	1

The empirical formula is C_2H_4O.

b $2 \times 12 + 4 \times 1 + 1 \times 16 = 44$

$\frac{88}{44} = 2$

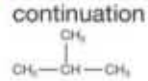
The molecular formula is $C_4H_8O_2$.

4 ▶ a Test: Add bromine water (1)

Result with compound 1: Solution changes colour from orange to colourless (1)

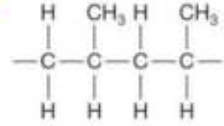
Result with compound 2: Solution stays orange (1)

b 1 mark for the correct structure; 1 mark for the continuation bonds

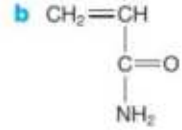


c Poly(but-2-ene) (1)

5 ▶ a



b



PHYSICS

UNIT 1 ANSWERS

CHAPTER 1

1 ▶ 8 m/s

2 ▶ **a** 10 500 m (10.5 km)
b 105 000 m (105 km)
c 630 000 m (630 km)

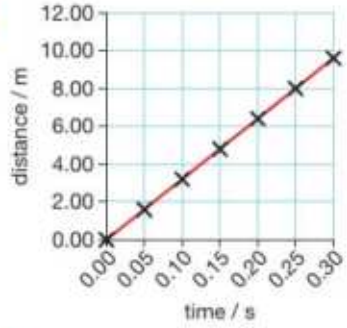
3 ▶ 4000 s

4 ▶ **a** D **b** C **c** A **d** B

5 ▶



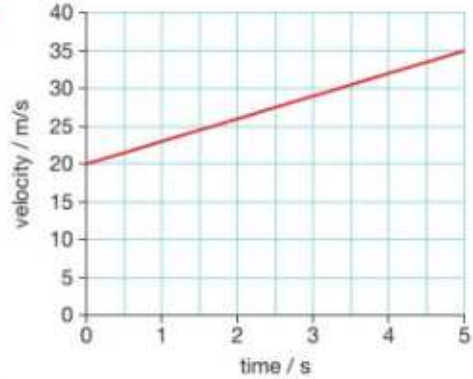
6 ▶



$$\text{gradient} = \frac{\text{distance}}{\text{time}}$$
$$= \frac{8\,\text{m}}{0.25\,\text{s}}$$
$$= 32\,\text{m/s}$$

7 ▶ **a** The car is moving at constant velocity (speed).
b Time interval between first and seventh drip is 15 s (6 × 2.5 s) so average speed is 135 m ÷ 15 s = 9 m/s.

8 ▶ **a**



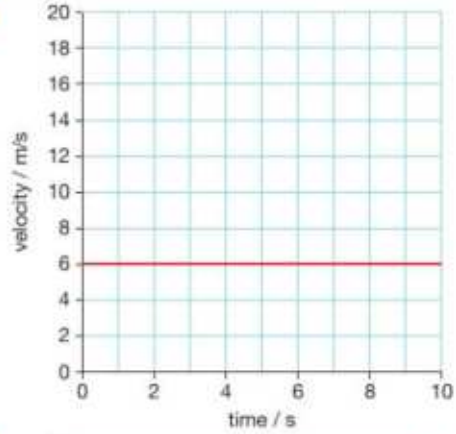
b Distance travelled is given by the area under the graph. (Divide area into a rectangle and a triangle.)
= (5 s × 20 m/s) + (0.5 × 5 s × 15 m/s) = 137.5 m

9 ▶ **a** Average speed is found by dividing the total distance a body has travelled by the time it has taken; the speed may vary from moment to moment during this time. The instantaneous speed is the speed at which the body is travelling at a moment in time.

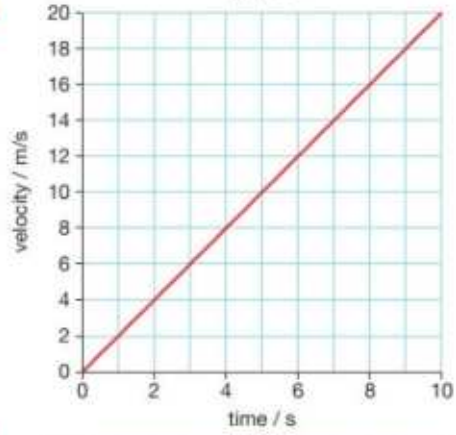
b Speed is a scalar quantity – it is distance travelled divided by time without regard to direction. Velocity is a vector quantity – it is speed in a specified direction.

10 ▶ 4 m/s²

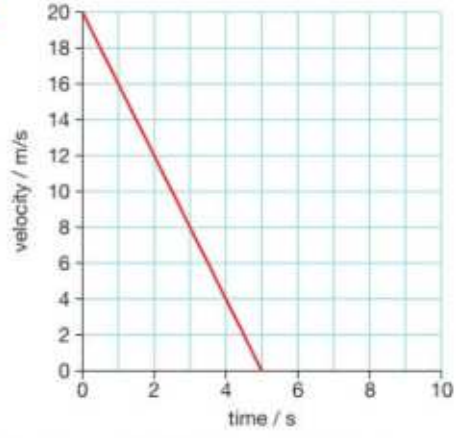
11 ▶ **a**



b



c



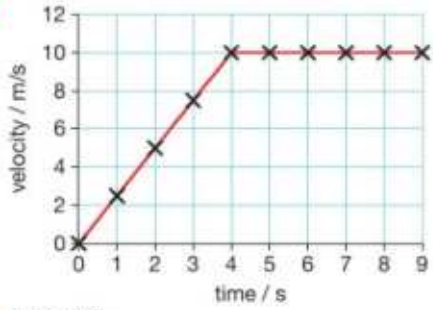
12 ▶ **a** 3 m/s **b** 15 m/s **c** 75 m/s

13 ▶ **a** B **b** A **c** D **d** C

14 ▶



15 ▶ a



b 2.5 m/s²

c i 20 m **ii** 50 m

d average speed = $\frac{\text{total distance travelled}}{\text{time taken}}$

$= \frac{70\,\text{m}}{9\,\text{s}}$

$= 7.78\,\text{m/s}$

16 ▶ The total distance travelled increases with the square of the time from the start, 0.5 m after 1 s, 2.0 m after 2 s, 4.5 m after 3 s, etc. Calculating the average velocity over each 1 s time interval (between the drips) and then plotting a graph of average velocity against time allows the acceleration to be calculated from the gradient of the graph. The acceleration is 1 m/s².

17 ▶ a v = final velocity; u = initial velocity; a = acceleration; s = displacement

b 32 m

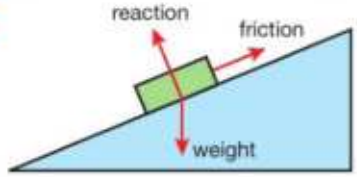
CHAPTER 2

1 ▶ a gravity **b** friction
c normal reaction or contact force

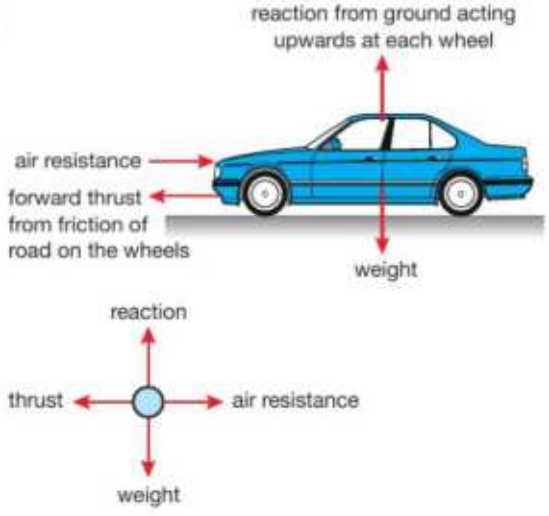
2 ▶ friction and air resistance (or viscous drag)

3 ▶ a 1200 N **b** 1250 N **c** 50 N **d** red

4 ▶



5 ▶

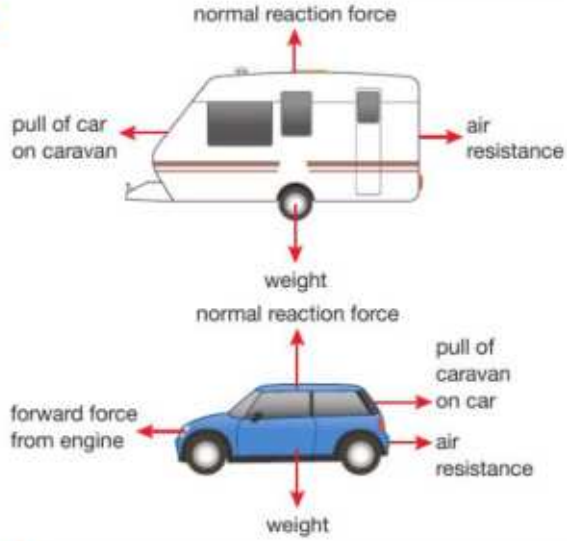


6 ▶ Any two sensible examples, for example: Without friction, objects would not be able to start moving from a stationary position, or stop moving when in motion. It would not be possible to build things because it would be difficult to pick up the building materials, and structures rely on friction to remain intact. Walking would be impossible without friction acting between your feet and the ground. Climbing a rope would be impossible without friction acting between your hands and the rope.

7 ▶



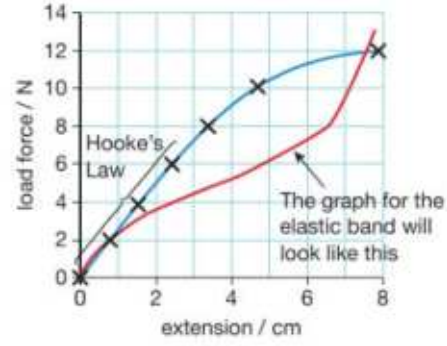
8 ▶



9 ▶ a

Load force on spring / newtons	Length of spring / cm	Extension of spring / cm
0	5.0	0.0
2	5.8	0.8
4	6.5	1.5
6	7.4	2.4
8	8.3	3.3
10	9.7	4.7
12	12.9	7.9

b c d



CHAPTER 3

1 ▶ A force that is not balanced by a force in the opposite direction. An accelerating car has an unbalanced force when the forwards force from the engine is bigger than the backwards force from air resistance.

2 ▶ From the equation *force = mass × acceleration* ($F = ma$) we can see that if F, the thrust force of the rocket engines, is constant and m, the mass of the rocket, decreases then the acceleration must increase.

3 ▶ **a** $F = ma$, where mass = 0.5 kg and acceleration = 4 m/s²

So $F = 0.5\,\text{kg} \times 4\,\text{m/s}^2 = 2\,\text{N}$

b $m = \frac{F}{a}$, where force = 200 N and acceleration = 0.8 m/s²

So $m = \frac{200\,\text{N}}{0.8\,\text{m/s}^2} = 250\,\text{kg}$

c Use $a = \frac{F}{m}$, where force = 250 N and mass = 25 kg

So $a = \frac{250\,\text{N}}{25\,\text{kg}} = 10\,\text{m/s}^2$

4 ▶ **a** Thinking distance is the distance a car travels after the driver has seen a hazard but *before* the driver applies the brakes; during this period the car is not decelerating.

b The braking distance is the distance travelled by the car *after* the driver has started braking and the car is decelerating to rest.

c The overall stopping distance is the sum of the thinking distance and the braking distance.

5 ▶ The braking distance of a car depends on the speed at which the car is travelling and the braking force that can be applied without the car skidding (as skidding means the car is out of control). The maximum braking force will be limited by factors that affect the friction between the car tyres and the road surface – for example, the condition of the tyres and the road surface. If the road surface is wet, icy or oily, friction will be reduced. The braking distance is greater if the speed of the car is higher or the maximum safe braking force is reduced.

6 ▶ **a** 0.75 s (the period during which the velocity of the car is constant at 24 m/s)

b 18 m (given by the area under the velocity–time graph during the first 0.75 s)

c 2.5 s (the period during which the velocity of the car is decreasing to zero)

d 48 m (the sum of the thinking distance and the braking distance – the total area under the graph)

7 ▶ **a** Use *weight = mass × gravity*

mass of apple in kg = 0.1 kg

strength of gravity on the Earth is approximately 10 N/kg

weight of apple on the Earth = 0.1 kg × 10 N/kg = 1 N

b Use *weight = mass × gravity*

mass of apple in kg = 0.1 kg

strength of gravity on the Moon is approximately 1.6 N/kg

weight of apple on the Moon = 0.1 kg × 1.6 N/kg = 0.16 N

8 ▶ The factors affecting the drag force on a high-speed train are:

- the speed of the train
- the shape of the train
- the direction of any wind that may be blowing
- (harder) the viscosity of the air that the train is travelling through; this will depend on temperature, humidity, etc.

9 ▶ See page 522 for a description of a suitable experiment.

10 ▶ At **A**: velocity is zero at start, so air resistance is zero and the unbalanced force is **downwards** (and is due to gravity or the weight of the parachutist).

At **B**: as the velocity of the parachutist increases, so does the size of the upward air resistance force – so the **unbalanced downwards force is smaller**.

At **C**: the velocity of the parachutist has increased to the point where the upward air resistance force is exactly the same as the downward force of gravity on the parachutist – the **unbalanced force is zero** and the parachutist has reached terminal velocity.

At **D**: the parachutist has opened her parachute. This greatly increases the upward air resistance force so the **unbalanced force** on the parachutist is now **upwards**. The parachutist's velocity decreases.

At **E**: as the parachutist slows down, the upward air resistance force due to the parachute decreases. This means that the **unbalanced upward force is smaller** (so the rate of deceleration of the parachutist decreases).

At **F**: the parachutist has slowed to a velocity at which the upward acting air resistance is once again equal to the downward acting force of gravity. The **unbalanced force is again zero.** (But note that the effect of opening the parachute is to make the new terminal velocity lower.)

END OF UNIT 1 QUESTIONS

1 ▶ **a** B (1) **b** D (1) **c** A (1) **d** C (1)

2 ▶ **a** B (1)

b i Displacement is distance travelled in a specified direction. Distance is how far you have travelled, not taking into account any changes in your direction of travel. (2)

ii 1 m vertically above the ground (1)

c i The ball falls with an acceleration downwards, $a = 10\,\text{m/s}^2$ (1)

The downward displacement of the ball on reaching the ground, $s = 3\,\text{m}$ (1)

The ball had an initial velocity, $u = 0\,\text{m/s}$ (1)

So $v^2 = u^2 + 2as$ gives $v^2 = 0^2 + 2 \times 10\,\text{m/s}^2 \times 3\,\text{m}$ (1)

$v = \sqrt{60\,\text{m}^2/\text{s}^2} = 7.75\,\text{m/s}$ (1)

You need to find the answer to **iii** first!

iii Time for the tennis ball to reach the ground,

$t = \frac{v - u}{a}$ (1)

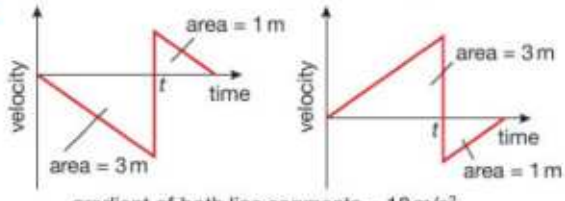
$t = \frac{7.75\,\text{m/s}}{10\,\text{m/s}^2} = 0.775\,\text{s}$ (1)

ii Average speed = $\frac{\text{distance travelled}}{\text{time taken}}$ (1)

Average speed = $\frac{3\text{ m}}{0.775\text{ s}}$ = 3.87 m/s (1)

d From the area beneath the graph line (1)

e



gradient of both line segments = 10 m/s²

2 marks for shape showing acceleration and abrupt change in direction, 1 mark for value of *t* as calculated in **c iii**, 1 mark for labelling area of larger triangle 3 m, 1 mark for labelling area of smaller triangle 1 m, and 1 mark for stating that the gradient of both line segments is the acceleration due to gravity, taken as 10 m/s².

The left-hand sketch graph assumes that up is positive for velocity; the right-hand sketch graph assumes that down is positive for velocity. Either is correct.

3 ▶ a i The load force on the wire (from the number of weights) (1)

ii The extension of the wire (1)

iii Temperature / type of wire / diameter of wire / initial length of wire under test (1)

b Using $F = mg$ (1)

c *1 mark for each point in italics and 1 mark for any other from this list (max 5 marks):*

Note type of wire

Monitor temperature during experiment

Measure diameter of wire under test with micrometer

Measure the extension produced by a range of increasing load forces

Measure the extension produced by the same load forces as the wire is unloaded

Plot a graph of extension against load force

Draw the best fit line through the plotted points

If best fit line is a straight line through the origin of the axes then wire obeys Hooke's law

d Use a longer length of wire (1). (This will increase the extension produced by each load, improving the accuracy of the measurements.)

Add weights one by one and note the extension produced by each increase in load; then remove the weights one by one and note the extension at each value of load during unloading (1).

If the extension is elastic: the extension at each value of load should be the same during loading and unloading (1) / the wire should return to its original length when the load is reduced to the starting value (1).

UNIT 2 ANSWERS

CHAPTER 4

1 ▶ a 3 W **b** 50 V **c** 0.26 A

d 100 W × 18 000 s = 1 800 000 J (1800 kJ)

2 ▶ a The kettle is designed for a voltage of 230 V. At this voltage, 1.5 kJ of electrical energy is transferred into heat energy each second.

b $I = \frac{P}{V} = \frac{1500\text{ W}}{230\text{ V}} = 6.52\text{ A}$. The fuse should be rated at around 7 A or above. The next common rating above this is 13 A, so a 13 A fuse is needed.

c Electrical energy is being transferred at a rate of 100 J/s in the 100 W bulb but only at 60 J/s in the 60 W bulb.

3 ▶ a It can be reset. It does not need to be replaced every time it breaks the circuit.

b So no electrical energy can enter the appliance. If the switch was in the neutral wire, electricity could enter the appliance and possibly cause a shock if the appliance was faulty.

c The outer casing is made from an insulator, e.g. plastic.

4 ▶ The power ratings of most appliances are shown on the appliance itself.

CHAPTER 5

1 ▶ a Electrons

b There are many free charge carriers (free electrons) in metals, but very few in a plastic.

c i 3 C **ii** 1800 C **iii** 10 800 C

2 ▶ a i Charge can travel all the way around a complete circuit. An incomplete circuit has gaps, so charge cannot travel all the way around it.

ii In a series circuit, there is only one path for the current to follow. In a parallel circuit, there is more than one path for the current to follow.

b S1 open: bulbs, A, B and C will go out.

S2 open: bulbs A, B and C will go out.

S3 open: bulbs D, E, F, G and H will go out.

S4 open: bulbs D and E will go out.

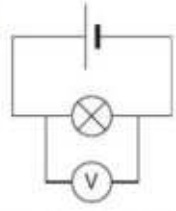
S5 open: bulbs F, G and H will go out.

S6 open: bulbs G and H will go out.

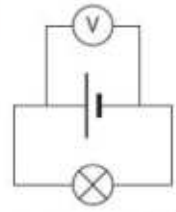
c All the bulbs will glow with equal brightness.

d It is a series circuit; therefore the current through all bulbs is the same.

3 ▶ a i



ii



b As each coulomb of charge passes through the 1.5 V cell, it receives 1.5 J of electrical energy.

4 ▶ a In the positions shown, the bulb will glow. If S1 is moved to B, the circuit is incomplete and the bulb will be turned off. If S2 is then moved to D, the circuit is again complete and the bulb will glow. If S2 is moved to D while S1 is still in position A, the circuit is incomplete and the bulb will be turned off.

b Turning lighting on and off from the top and bottom of a staircase.

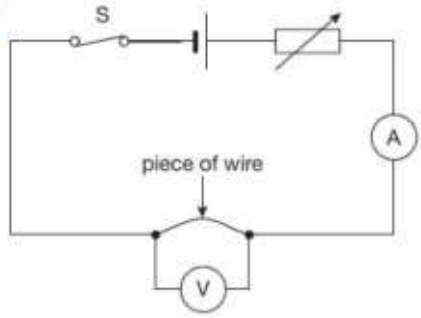
5 ▶ In parallel. If the lights are wired in series, the current through the string of lights will be too small to make them glow, and if the circuit is broken at any point (e.g. by a faulty bulb), all the bulbs will go off.

6 ▶ If all parts of the cooker are connected in series, turning one part on will turn on all the other parts as well.

CHAPTER 6

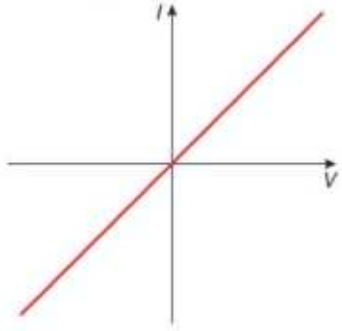
1 ▶ a The current that flows through a conductor is directly proportional to the potential difference (or voltage) across its ends, provided its temperature remains constant.

b

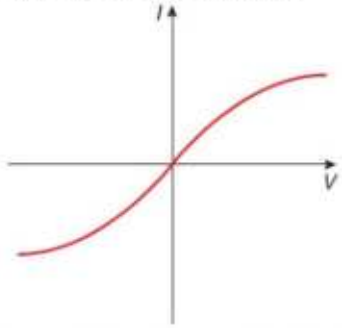


c Close the switch and record the readings on the ammeter and voltmeter. Use the variable resistor to change the resistance and take new readings. Repeat this at least six times. A graph of *I* against *V* should show a straight line passing through the origin, confirming Ohm's law.

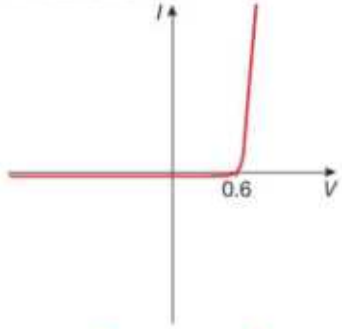
d i A straight line graph passing through the origin, indicating a constant resistance.



ii As the current increases, the filament gets hotter and its resistance increases.



iii The resistance in one direction is very high, i.e. the diode will not conduct. The resistance in the opposite direction is much smaller, i.e. the diode will conduct.

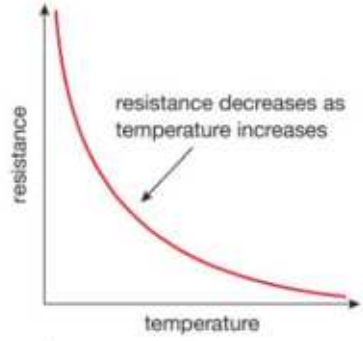


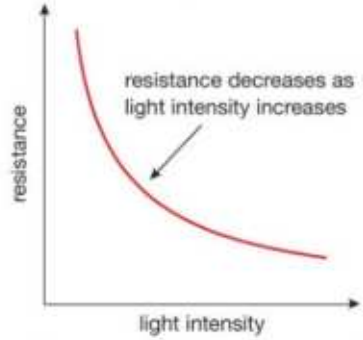
2 ▶ a 4Ω **b** 0.24A **c** 30V

3 ▶ a i Resistance decreases as temperature increases / resistance increases as temperature decreases.

ii Resistance decreases as light intensity increases.

iii





b Thermistors can be used in temperature-sensitive circuits such as fire alarms and thermostats. LDRs can be used in light-sensitive circuits such as automatic lighting controls.

END OF UNIT 2 QUESTIONS

1 ▶ **a** B (1) **b** D (1) **c** A (1) **d** B (1)

2 ▶ electrons (1); coulomb (1); energy (1); resistance (1); lower (1)

3 ▶ **a** Y is an ammeter (1); Z is a voltmeter (1)

b variable resistor (1)

c It can be used to change the current. (1)

d 2.5 A (1)

e 4.0 V (1)

f $R = \frac{4.0\,V}{2.0\,A}$ (1)

$= 2.0\,\Omega$ (1)

g It increases. (1)

4 ▶ **a** $I = \frac{V}{R}$ (1)

$= \frac{12\,V}{10\,\Omega} = 1.2\,A$ (1)

b $Q = I \times t$ (1)

$= 1.2\,A \times 5\,s = 6\,C$ (1)

c $E = V \times I \times t$ (1)

$= 12\,V \times 1.2\,A \times 60\,s = 864\,J$ (1)

5 ▶ **a** $I = \frac{P}{V}$ (1)

$= \frac{2300\,W}{230\,V}$ (1)

$= 8.7\,A$ (1)

b 13 A (1)

c A double-insulated appliance has an outer casing made of plastic or some other insulating material. (1)

Even if there is a fault inside the appliance, making a live wire touch the casing, the user will not get a shock. (1)

d $R = \frac{V}{I} = \frac{230\,V}{8.7\,A} = 26.4\,\Omega$ (1)

6 ▶ **a** Two insulating materials are rubbed together (1), which transfers some electrons from one material to the other (1). The material that gains electrons has a negative charge (1) and the material that loses electrons has a positive charge (1).

b i Any static charge that has built up on the aircraft in flight (1) can be discharged through the earthing wire (1) instead of causing a spark which could ignite fuel vapour (1).

ii A wire is attached from the aircraft to a point on the tanker. (1)

c Electrostatic painting attracts paint to the object being painted (1) so less paint is wasted (1) and therefore less paint is needed (1).

d An inkjet printer uses the fact that opposite charges attract (1) and similar charges repel (1) to direct drops of ink to the correct places on the paper (1).

7 ▶ **a** Any four uses, such as cooking, heating water for washing, heating the house, drying hair, etc. (1 mark per use)

b A fault in an appliance could lead to a live wire touching the casing ($\frac{1}{2}$); in this situation, the presence of an earth wire conducts the current to earth and blows the fuse ($\frac{1}{2}$). This prevents someone touching the casing getting a shock ($\frac{1}{2}$). A double-insulated hairdryer has an insulating case, so the person cannot get a shock even if the fuse has not blown ($\frac{1}{2}$).

8 ▶ **a** 10 V (2) **b** 2 V (2) **c** 12 V (1)

UNIT 3 ANSWERS

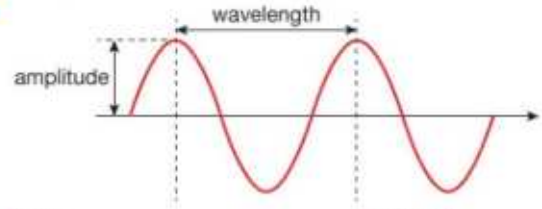
CHAPTER 7

1 ▶ **a** The vibrations of a transverse wave are **across** the direction in which the wave is moving. The vibrations of a longitudinal wave are **along** the direction in which the wave is moving.

b Transverse waves: light (or any other electromagnetic wave) or surface water waves

Longitudinal waves: sound waves

c



2 ▶ **a** 0.4 s **b** 2.5 Hz

3 ▶ **a** $f = \frac{v}{\lambda} = \frac{1500\,m/s}{1.5\,m} = 1000\,Hz$

b $T = \frac{1}{f} = 0.001\,s$

4 ▶ **a** The wavefronts are squashed closer together as the car approaches.

b It would be higher.

c It would be lower than when the car is stationary.

5 ▶ Rays of light from the fish have been refracted at the surface of the water so the hunter does not see the real position of the fish.

CHAPTER 8

1 ▶ **a** They all: transfer energy; are transverse waves; travel at the same speed through a vacuum; can be reflected, refracted and diffracted.

b Light, microwaves and radio waves

c Microwaves and infra-red waves

d Gamma rays

e Infra-red

f Microwaves

2 ▶ **a** Water molecules within the food absorb the microwaves and become hot, so the food cooks throughout, not just from the outside as in the case of a normal oven.

b X-rays pass easily through soft body tissue but cannot travel through bones. Therefore bones leave 'shadows' on X-ray photographs, which show the shape of the bone and can show if bones have been broken.

c The Earth's ozone layer absorbs large quantities of the Sun's UV radiation. If this layer is damaged, more UV light will reach the surface of the Earth. UV light is harmful to human eyes and can cause skin cancer.

d Exposure to gamma radiation kills the micro-organisms that cause food to decay.

3 ▶ a i Wear lead lined clothes, stand behind a lead screen

ii Wear clothing, use sunblock

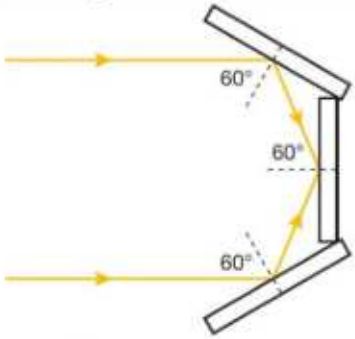
b X-rays: overexposure can cause cancer
Ultraviolet: overexposure can be harmful to human eyes and can cause skin damage such as sunburn and/or blistering

4 ▶

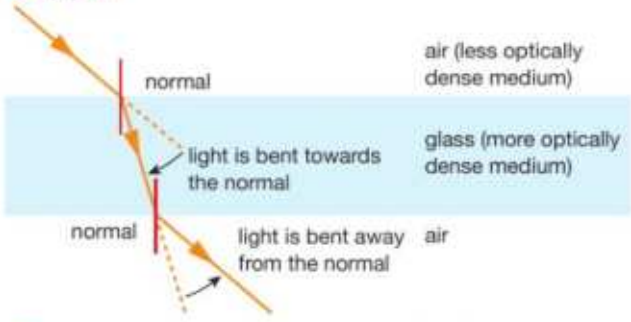
Type of radiation	Possible harm	Precautions
x-rays	cancer	lead screening
microwaves	cancer	metal screening
infra-red	skin burns	avoid over-exposure
ultraviolet	cancer/skin damage	glasses, sunblock

CHAPTER 9

1 ▶ Your diagram could look something like this:

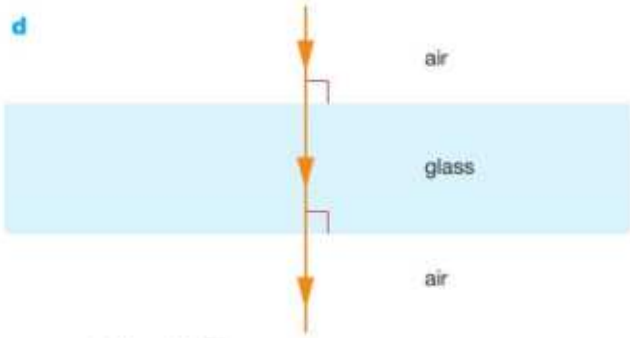


2 ▶ a and **b**



c As the ray of light enters the glass block, it slows down and is refracted towards the normal. As the ray leaves the glass block, its speed increases and it is refracted away from the normal.

d



3 ▶ a $n = \frac{\sin i}{\sin r} = \frac{\sin 55°}{\sin 31°} = 1.59$

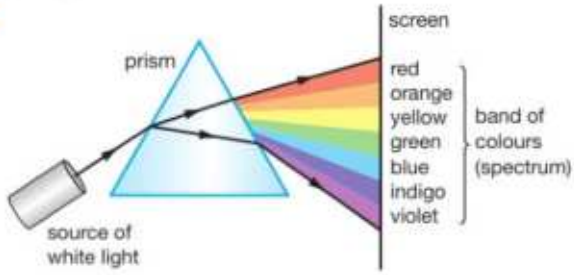
b $\sin r = \frac{\sin i}{n} = \frac{\sin 45°}{1.59} = 0.445$

$r = 26.4°$

c $\sin c = \frac{1}{n} = \frac{1}{1.59} = 0.629$

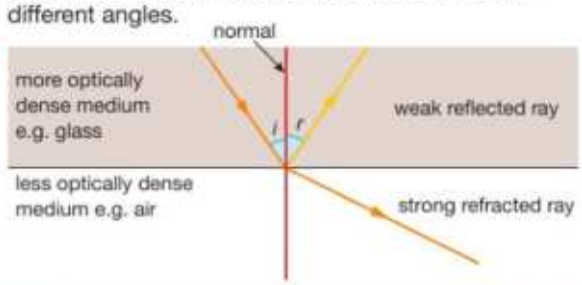
$c = 39°$

4 ▶ a

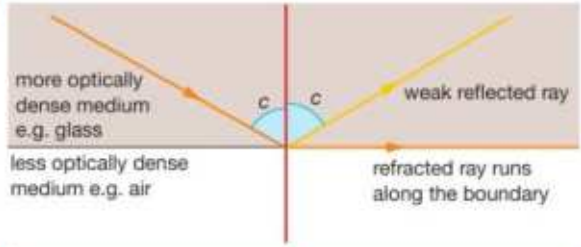


b White light is composed of a mixture of colours. Because each colour travels at a different speed through the prism, the different colours are refracted through different angles.

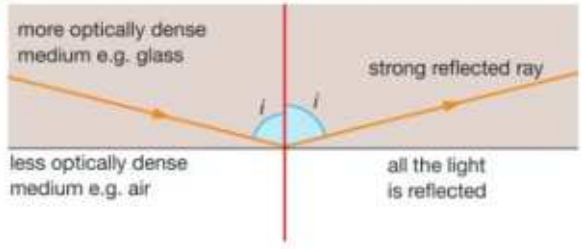
5 ▶ a



b

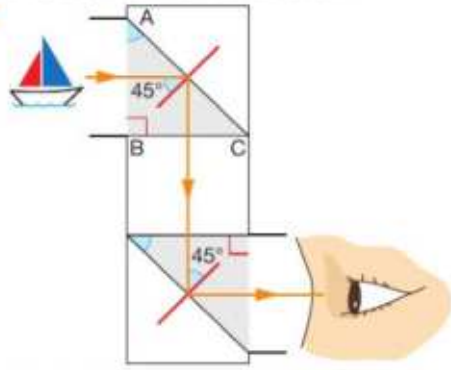


c



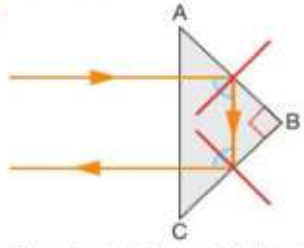
6 ▶ a If a ray of light travelling from glass or water to air strikes the boundary between the two at an angle greater than the critical angle, the ray is reflected by the boundary and is not refracted. This phenomenon is called total internal reflection.

b



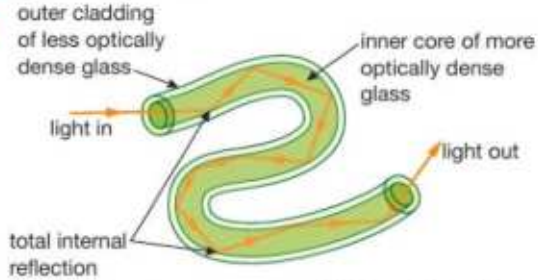
c The final image created by a prismatic periscope is likely to be sharper and brighter than that produced by a periscope which uses mirrors.

d



Bicycle reflectors and binoculars use prisms to turn light through 180°.

7 ▶ a



As the fibres are very narrow, light entering the inner core always strikes the boundary of the two glasses at an angle that is greater than the critical angle. This means that all the light is reflected (total internal reflection).

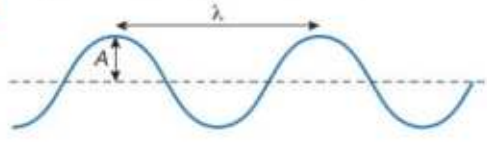
b Optical fibres are used in the construction of endoscopes. Bundles of optical fibres carry light into and out of a patient's body. Images of the inside of the body can be created from the reflected light.

c Telecommunications

END OF UNIT 3 QUESTIONS

1 ▶ a B (1) **b** D (1) **c** A (1)

2 ▶ a



b i $f = \frac{v}{\lambda}$ (1)

$= \frac{20\,\text{m/s}}{2.5\,\text{s}}$ (1)

$= 8\,\text{Hz}$ (1)

ii $T = \frac{1}{f}$

$= \frac{1}{8\,\text{Hz}}$

$= 0.125\,\text{s}$ (1)

3 ▶ a A less dense glass, i.e. a glass with a lower refractive index. (1)

b A more dense glass, i.e. a glass with a higher refractive index. (1)

c The light strikes the boundary at an angle greater than the critical angle (1) so total internal reflection takes place (1).

d Optical fibres are used in endoscopes. These allow doctors / surgeons to see inside the body, and make keyhole surgery possible. (1)

4 ▶ a i The vibrations of a longitudinal wave are along the direction in which the wave is travelling (1). The vibrations of a transverse wave are across the direction in which the wave is travelling. (1)

ii Sound waves are longitudinal waves. (1) Light waves and surface water waves are transverse waves. (1)

b To improve the accuracy of the experiment. (1)

c

Experiment	Time in seconds	Speed of sound in m/s
1	2.95	339
2	3.00	333
3	2.90	345
4	3.20	313
5	2.95	339

(1 mark for each row of table completed)

Average speed of sound from experiment = 334 m/s (1)

d No. The effect of any wind is cancelled out as the sound travels in one direction as it approaches the building, and in the opposite direction as it returns.

5 ▶ a Radio waves, microwaves, infra-red waves, visible spectrum, ultraviolet waves, X-rays, gamma rays. (2 marks for all correct; lose 1 mark for each wave in the wrong position (no negative marks))

b All these waves transfer energy (1), are transverse waves (1), travel at the speed of light in a vacuum (1), can be reflected, refracted and diffracted (1).

c Radio waves – communication (1); microwaves – communication / cooking (1); infra-red waves – cooker / heater / remote control / night vision (1); visible light – seeing / communication (1); ultraviolet waves – fluorescent tubes / tanning lamps (1); X-rays – X-radiography (1); gamma rays – sterilising food or equipment / radiotherapy (1)

d Gamma rays (1), X-rays (1) and ultraviolet waves (1)

e Radio waves (1), microwaves (1) and visible light (1)

6 ▶ a i $n = \frac{\sin i}{\sin r} = \frac{\sin 38}{\sin 24} = 1.51$ (4)

ii $n = \frac{1}{\sin c}$, $c = 41.3$ (2)

b $n = \frac{1}{\sin c} = \frac{1}{\sin 42} = 1.49$ (3)

UNIT 4 ANSWERS

CHAPTER 10

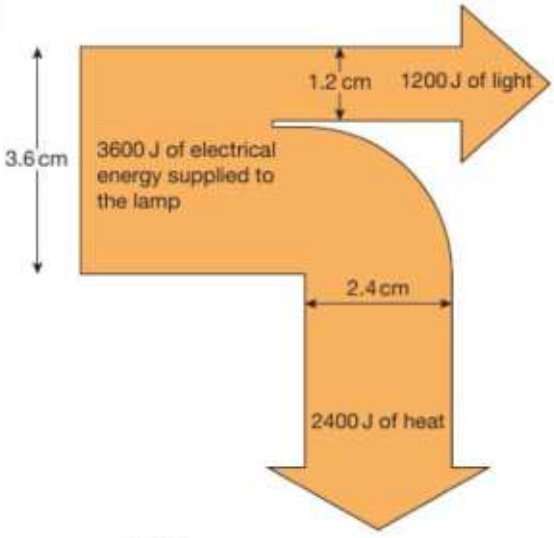
1 ▶ a Stored chemical energy in the battery → electrical energy in the circuit → heat and light in the lamp filament

b Stored chemical energy in the paraffin wax → heat and light as the candle burns

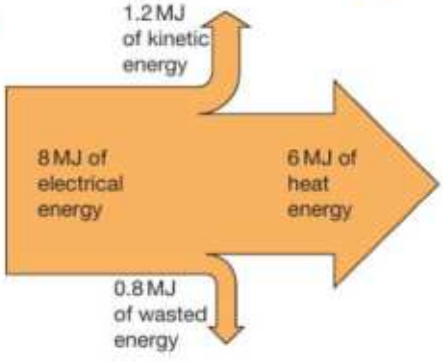
c Kinetic energy of moving hands → heat energy

d Stored energy in the stretched elastic of the trampoline → kinetic energy of the trampolinist moving upwards → gravitational potential energy as the trampolinist slows to a halt at the top of the bounce

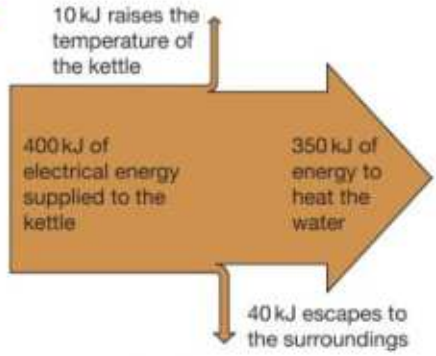
2 ▶ a



b



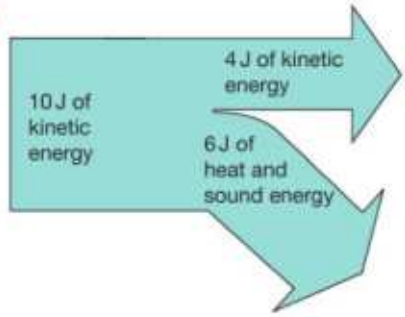
3 ▶ a



b Efficiency $= \frac{350}{400} = 0.875$

4 ▶ a 6 J of energy is converted to heat in the ball and the ground and to sound.

b



CHAPTER 11

1 ▶ a Some of the heat energy in the tea is transferred to the spoon. Also, the metal spoon is a good conductor of heat, so it increases the area from which the heat of the tea can be lost.

b The plastic lid traps a layer of air above the tea. Air is a poor conductor of heat. The layer of trapped air also greatly reduces heat loss from the surface of the hot tea by preventing convection currents in the air above the cup. It also reduces the amount of heat lost through evaporation.

2 ▶ a Copper is a very good conductor of heat. This is an advantage, because it allows the water in the kettle to heat up quickly, as the energy from the stove is easily transferred through the copper to the water within the kettle. However, it could also be considered to be a disadvantage, as the heat transfer from the water inside the kettle to the outer surface of the kettle is also rapid.

b A shiny surface reduces heat loss by thermal radiation. A kettle allowed to go black would radiate more heat from its surface than a shiny, clean one.

3 ▶ Although paper is a poor thermal conductor, it is thin, so heat can transfer through it quite rapidly. This heat energy is then rapidly conducted away from the paper by the brass section, because brass is a very good thermal conductor. Wood is a poor thermal conductor, so heat is transferred away from the paper much more slowly. As a result, the temperature of the paper rises enough for it to start to scorch.

4 ▶ Both benches will be in thermal equilibrium with the surroundings; that is, they will both be at the same temperature as their surroundings and, therefore, each other. Thus the metal bench is not actually colder than the wooden one *to start with*. However, the metal bench conducts heat much more readily than the wooden bench. Heat from the body is quickly conducted away from the body by the metal bench, and the region beneath the person's body remains close to the air temperature. Heat travels much more slowly through wood, so the region under the person sitting on the wooden bench *does* warm up. As its temperature gets close to the person's body temperature, the rate at which heat is transferred from the body into the bench is reduced and the bench does not feel as cold.

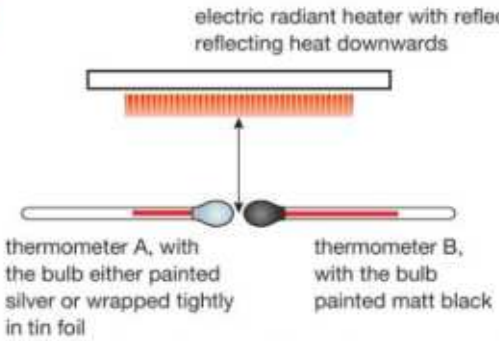
5 ▶ **a** Water is a relatively poor thermal conductor. As it is a fluid (capable of flowing or moving around), the main mechanism of heat transfer is convection. Convection means that heated water, which expands and becomes less dense, is displaced upward by colder and therefore denser water. If the heating element was positioned near the top of the kettle, only the top layer of water would be heated, because the colder denser water would be *below* the element and would not be directly heated by contact with the heating element.

b At the top. Air cooled by the element will become more dense and will sink down the freezer. If the cooling element was placed at the bottom, only the bottom layer of air would become cold.

6 ▶ The slots at the top allow air that has been heated by the computer circuitry – and thus become less dense – to be pushed upwards by colder, denser air drawn in through the slots in the base of the computer case. This convection current means that a steady stream of cooler air is drawn across the electronic circuitry, helping to keep it cool. Convection does not take place so effectively if the ventilation slots are in the sides of the case at the same level, so fans are necessary to maintain a sufficient circulation of cool air across the circuitry.

7 ▶ The fire heats the air in the right-hand shaft in the diagram. This air expands and becomes less dense, and is therefore pushed upwards by colder, denser air drawn down the other shafts in the mine. This ensures there is a steady circulation of fresh (colder, denser) air drawn down the shaft on the left of the diagram.

8 ▶ **a**



The apparatus above will show if heat is absorbed more readily by thermometer B (with a black bulb) than by thermometer A (with a shiny bulb).

b Measure the initial temperatures on each thermometer and then take readings at 30 s intervals.

c The thermometers should be identical apart from the bulbs and should be placed at the same distance from the heater. The apparatus should be screened from draughts and other sources of heat. The experiment should be repeated.

d Placing the thermometers below the heat source means that heat cannot be transferred from the source to the thermometers by convection. Air is a very poor thermal conductor so little heat will be transferred by conduction. If the temperature shown on thermometer B rises more quickly than the temperature shown on thermometer A we can therefore conclude that the blackened bulb of thermometer B is a better absorber of thermal radiation than the shiny bulb of thermometer A.

CHAPTER 12

1 ▶ **a** A wide range of answers possible, e.g. rubbing hands to warm them.

b Heat water to produce steam, which is then used to rotate a turbine. The turbine can then raise a weight.

2 ▶ **a** joule

b The joule is the amount of work done when a force of 1 N is applied through a distance of 1 m in the direction of the force.

c For each, use: work done = force × distance

i $W = 6 \times 1\,\text{N} \times 0.8\,\text{m} = 4.8\,\text{J}$

ii $W = 100\,000\,\text{N} \times 200\,\text{m} = 20\,\text{MJ}$

iii $W = (60\,\text{kg} \times 10\,\text{N/kg}) \times 2.8\,\text{m} = 1680\,\text{J}$

iv $W = (350\,\text{kg} \times 10\,\text{N/kg}) \times 45\,\text{m} = 157.5\,\text{kJ}$

3 ▶ Use gravitational potential energy = mgh

GPE = 200 000 000 kg × 10 N/kg × 800 m = 160 000 MJ

4 ▶ **a** Use the formula $\text{KE} = \frac{1}{2}mv^2$ where m is the mass of the moving object in kg and v is its velocity in m/s to give the KE in joules.

b **i** $\text{KE} = \frac{1}{2} \times 80\,\text{kg} \times (9\,\text{m/s})^2 = 3240\,\text{J}$

ii $\text{KE} = \frac{1}{2} \times 0.0002\,\text{kg} \times (50\,\text{m/s})^2 = 0.25\,\text{J}$

iii $\text{KE} = \frac{1}{2} \times 0.06\,\text{kg} \times (24\,\text{m/s})^2 = 17.28\,\text{J}$

5 ▶ At the top of the stone's flight, all of its initial KE is converted to GPE, so 48 J = mgh, where $m = 0.04$ kg and $g = 10$ N/kg. Hence: $h = \dfrac{48\,\text{J}}{0.04\,\text{kg} \times 10\,\text{N/kg}} = 120\,\text{m}$

6 ▶ The initial GPE that the coin has is completely converted to KE when it reaches the ground, so $mgh = \frac{1}{2}mv^2$.

As mass, m, is common to both sides of the equation, it cancels to give $gh = \frac{1}{2}v^2$.

Rearranging, we can calculate the velocity $v = \sqrt{(2gh)}$, so $v = \sqrt{(2 \times 10\,\text{N/kg} \times 80\,\text{m})} = 40\,\text{m/s}$.

Assumption: air resistance has little effect.

7 ▶ Power is the rate of doing work (or the rate of converting energy) and can be calculated using:

$$\text{power} = \frac{\text{work done in J}}{\text{time taken in s}}$$

The unit of power is the watt.

8 ▶ **a** Weight = mass × gravitational field strength, so the person weighs 400 N

b Total height = height of one step × number of steps = 4 m

c Work done = force × distance = 1600 J

d Power = $\frac{\text{work done}}{\text{time taken}}$ so the person's power output is 133 W

9 ▶ **a** **i** 144 km/h × 1000 = 144 000 m/h

ii $\frac{144\,000\text{ m/h}}{3600} = 40\text{ m/s}$

b KE = $\frac{1}{2}$ × 500 kg × (40 m/s)^2 = 400 000 J

c Assuming no energy is converted to other forms than movement (impossible in reality), the average power developed by the engine is: $\frac{400\,000\text{ J}}{5\text{ s}} = 80\,000\text{ W}$

END OF UNIT 4 QUESTIONS

1 ▶ **a** D (1) **b** C (1) **c** B (1) **d** A (1) **e** D (1)

2 ▶ **a** Work done = force × distance (1)
= 800 N × 30 m (1)
= 24 000 J (1)

b Power = $\frac{\text{energy transferred}}{\text{time taken}}$
= $\frac{24\,000\text{ J}}{16\text{ s (1)}}$
= 1500 W (1)

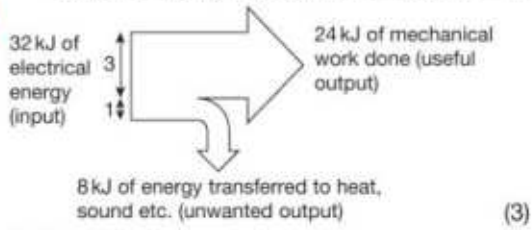
c **i** This means that only 75% of the electrical power supplied to the motor is transferred usefully in raising the load. (2)

ii Efficiency = $\frac{\text{useful power transferred}}{\text{total electrical power supplied}}$ (1)

Total electrical power supplied = $\frac{\text{useful power transferred}}{75/100}$ (1)

Total electrical power supplied = 2000 W = 2 kW (1)

d



(3)

3 ▶ **a** B (1)

b Once the rocket has left the launcher, it loses speed as KE is transferred to GPE. (1)

At the top of the flight, the rocket comes to a stop: KE is zero, GPE is maximum. (1)

The rocket then falls and gains speed as GPE is transferred to KE. (1)

It hits the ground with max KE, which is then transferred to heat, sound etc. (1)

4 ▶ **a** Any 3 from the following (1 mark each, maximum 3 marks)

Make the mass of ice in each experiment the same (1)

Ensure the initial temperature of the ice is the same in each experiment (1)

Ensure the initial temperature of the water in each tube is the same (1)

Make sure the source of heat is the same in each experiment (1)

Make sure the room temperature is the same during each experiment (1)

b **i** A C B (1) because heating directly beneath the ice, as in B, will mean that more energy is transferred to the ice directly (1). In C, the water in the tube will also need to heat up (1) and in A the water must be heated up and heat must transfer down through the water, which will take longer than in C. (1)

ii In B, the ice melts quickly because it is almost in direct contact with the heat source (conduction takes place through the glass wall and a thin layer of water).

In A and C, heat must be transferred through roughly the same length of water, but convection currents will transfer heat from the bottom of the tube in C, as the directly heated water becomes less dense and is pushed to the top of the tube by colder denser water.

This causes heat to be transferred to the top of the tube quite quickly. (1)

In tube A, convection will not transfer heat from the top of the tube to the bottom so conduction is the principal way in which heat can be transferred between the heated water at the top and the ice at the bottom. (1)

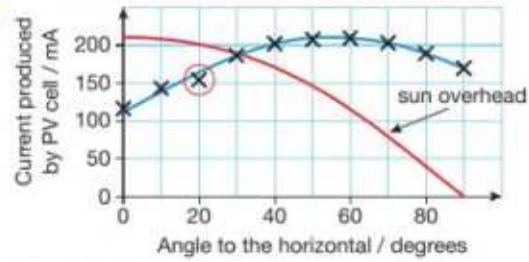
The water at the top can be boiling without the ice at the bottom melting quickly, so we can assume that water is a poor conductor of heat. (1)

5 ▶ **a** **i** the current through the load (1)

ii the angle between the plane of the PV cell and the horizontal (1)

iii Any one from: the distance between the lamp and the PV cell (1); the brightness of the lamp (1); the brightness of other lighting in the room (1), etc.

b



All points plotted correctly (2)

Sensible scales (1)

Scales labelled (1)

Smooth best fit line (1)

c i anomalous result ringed in red (1)
ii peak between 50° and 60° (1)

d i By raising the lamp, keeping the stand position where it is (and re-angling the lamp to keep the PV cell in the beam (1)
ii See red graph line:
Peak at 0° (any magnitude, likely to be greater than for original graph) (1)
Curves downwards (1)
To a very low level at 90° (1)

UNIT 5 ANSWERS

CHAPTER 13

1 ▶ **a** Submerged the crown in water and measured the volume of water displaced

b density = $\frac{\text{mass}}{\text{volume}}$, so mass = density × volume
mass of crown should be 19000 kg/m^3 × 0.0001 m^3
= 1.9 kg

2 ▶ **a** The person's weight will be spread out over the area of the ladder, so the pressure on the roof will be less.

b Area of one boot = 0.021 m^2
Pressure = $\frac{\text{force}}{\text{area}} = \frac{850\,\text{N}}{0.021\,\text{m}^2}$ = 40476 Pa

c Force = 850 N + 70 N = 920 N
Pressure = $\frac{920\,\text{N}}{0.3\,\text{m}^2}$ = 3067 Pa

3 ▶ **a** p = 0.1 m × 1000 kg/m^3 × 10 N/kg = 1000 Pa

b The gas pressure at point C is balancing the atmospheric pressure in the open section of the tube (point A) and the pressure of the 10 cm difference in water level between point A and point B. Therefore, the pressure of the gas at point C is:
100000 N/m^2 (100 kPa) + 1000 N/m^2 (from part a) = 101000 N/m^2 (101 kPa).

c Atmospheric pressure will be restored in the right-hand tube, so the water levels in both sides of the manometer will be equalised.

CHAPTER 14

1 ▶ As a substance is cooled, the pressure it exerts becomes smaller as the particles move more slowly. Absolute zero is the temperature at which the particles are not moving / the gas is exerting zero pressure.

2 ▶ **a** i 273 K ii 373 K iii 293 K
b i –23 °C ii –4 °C iii 32 °C

3 ▶ **a** The piston moves out. The air particles will move faster when they are heated, so there will be more, and harder, collisions with the walls of the container and the piston, increasing the pressure. The increased force on the piston will make it move outwards.

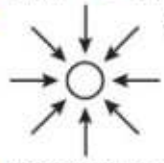
b As the beaker is pushed down, pressure from the water will tend to compress the air trapped in the beaker, so the particles in the air will be closer together.

c As the container is heated, the air particles inside will move faster. The pressure will increase, and may increase enough to force the cork out of the opening.

END OF UNIT 5 QUESTIONS

1 ▶ **a** B (1) **b** C (1) **c** C (1) **d** C (1) **e** D (1)

2 ▶ **a** (2)



b The pressure on the bubble decreases as it rises towards the surface of the cola (1)
so the bubble gets bigger (1)
because pressure × volume is constant (for a fixed mass of gas at constant temperature) (1)

3 ▶ **a** i The volume of the stone (1)
ii A measuring cylinder (1)
iii Any one from: make sure the stone does not splash water out of the big beaker (1); make sure the measuring cylinder is level (1); measure to the bottom of the liquid meniscus (1); look at the scale straight on (avoid parallax error) (1)

b i density = $\frac{\text{mass}}{\text{volume}}$ (1)
ii The mass must be measured using a digital balance (1)

4 ▶ h = 76 cm; convert to m = 0.76 m (1)
pressure = $h \times \rho \times g$
= 0.76 m × 13600 kg/m^3 × 10 N/kg (1)
= 103360 Pa (1)

UNIT 6 ANSWERS

CHAPTER 15

1 ▶ c, e, g

2 ▶ **a**



b

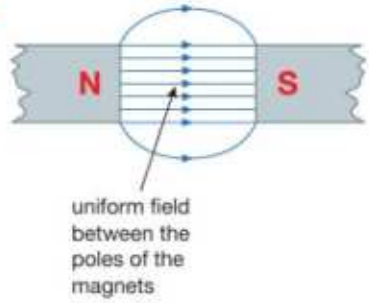


Similar poles repel and opposite poles attract.

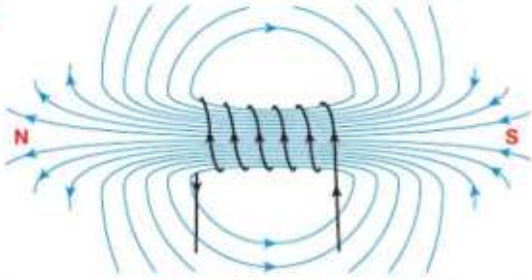
3 ▶ **a** Shape, strength and direction

b A field which has the same strength everywhere.

c



4 ▶ a



b The magnetic field is strongest where the field lines are closest together and weakest where the field lines are furthest apart.

c The directions of the magnetic field and its poles will also be reversed.

5 ▶ a When current passed through the wire, a magnetic field was created around it.

b From right to left. The magnetic field around the wire is circular, with the wire at its centre. The field is therefore in opposite directions on opposite sides of the wire.

c No. If the current flowing through the wire is reversed, the direction of the magnetic field around the wire will also be reversed.

6 ▶ a Iron loses its magnetism when the current through the coil is turned off, i.e. the electromagnet can be turned off. Steel retains its magnetism after the current / electromagnet has been turned off.

b Increase the current flowing through the coils, increase the number of coils.

CHAPTER 16

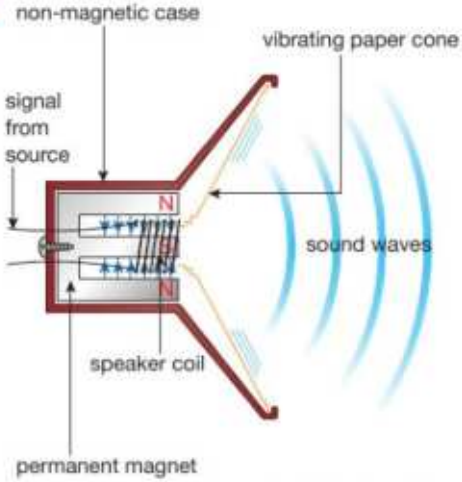
1 ▶ a The wire is pushed upwards.

b The wire is pushed downwards.

c The wire is pushed upwards.

d The wire is pushed with a larger force.

2 ▶ a



b Varying electric currents from the source create magnetic fields (around the speaker coil); the strength and direction of these fields change as the current changes. These changes make the speaker vibrate, creating the sound waves we hear.

3 ▶ a Large deflection on meter

b No deflection on meter

c Smaller deflection on meter than in **a** and in the opposite direction

d Meter deflects in the same direction as in **a**

END OF UNIT 6 QUESTIONS

1 ▶ a C (1) **b** D (1) **c** B (1)

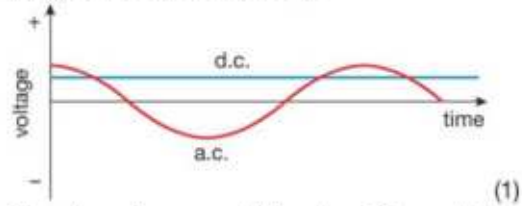
2 ▶ force (1); magnetic (1); loudspeakers (1); motors (1); coil (1); induced (1); dynamos (or generators) (1); generators (or dynamos) (1)

3 ▶ a As the cyclist pedals, a magnet rotates (1). Its magnetic field cuts through a coil (1), inducing current in the coil (1).

b When the cyclist stops pedalling, the magnet is stationary: there is no movement of the magnet and its magnetic field, so no current is produced. (1)

c A generator which produces alternating current. (1)

d Direct current (dc) flows in the same direction all the time. (1) Alternating current (ac) changes direction many times each second (1).



(1)

e The alternating current (1) makes 50 complete cycles each second. (1)

4 ▶ Increase the number of turns on the coil (1) or use a stronger magnet (1). He could pedal faster. (1)

5 ▶ a The permanent magnet will attract the iron armature but then not release it (1), so the hammer will not vibrate up and down (1).

b Iron is a magnetically soft material and therefore loses its magnetism when the current is turned off (1). Steel is a magnetically hard material and therefore retains its magnetism when the current is turned off (1). If the core of the electromaget was made from steel, the hammer would not vibrate up and down as the electromagnet was turned on and off (1).

UNIT 7 ANSWERS

CHAPTER 17

1 ▶

Atomic particle	Relative mass of particle	Relative charge of particle
electron	1	+1
proton	2000	–1
neutron	2000	0

2 ▶ a neutron **b** electron

c proton **d** proton

e electron

3 ▶ **a** The atomic number of an atom is equal to the number of protons in the atomic nucleus. This defines the chemical element. Different chemical elements have different atomic numbers.

b The mass number of an atom is equal to the total number of protons and neutrons in the nucleus.

4 ▶

	$^{3}_{2}$He	$^{13}_{6}$C	$^{23}_{11}$Na
protons	2	6	11
neutrons	1	7	12
electrons	2	6	11

5 ▶ **a** nucleons, protons, neutrons, +2

b electron, proton, neutron

c gamma, short

d electromagnetic

6 ▶ **a** **i** C **ii** B

b $^{1}_{1}p \rightarrow {}^{1}_{0}p + {}^{0}_{1}e$

7 ▶ Alpha radiation is stopped by card; since there is a drop in the detected radiation when a piece of card is placed between the source and the detector, the source must be emitting alpha particles.

Beta radiation is stopped by a thin sheet of aluminium; since there is no change in the detected radiation when an aluminium sheet is used, the source *cannot* be emitting beta particles.

Gamma radiation is stopped by a thick block of lead; since there is a drop in the detected radiation when a lead block is placed between the source and the detector, the source must be emitting gamma radiation.

8 ▶ **a** $^{234}_{90}\text{Th} \rightarrow {}^{234}_{91}\text{Th} + {}^{0}_{-1}e$

b beta decay

c $^{216}_{84}\text{Po} \rightarrow {}^{212}_{82}\text{Pb} + {}^{4}_{2}\text{He}$

d alpha decay

CHAPTER 18

1 ▶ **a** Background radiation is radiation produced by radioactive material in the Earth and in the Earth's atmosphere. It should be measured and taken into account when measuring the activity of radiation from a particular source.

b Natural background radiation is due to the decay of naturally occurring radioactive isotopes in the Earth that were formed when the Solar System was created. Natural radiation also results from high-energy particles that bombard the Earth. Artificial background radiation comes from man-made sources, rather than from the rocks that make up the Earth.

c Uranium in rocks in the Earth's crust (natural). Radioactive materials that have escaped into the environment from nuclear power stations (artificial). Fallout from atmospheric nuclear weapons testing in the 1950s and 1960s (artificial).

2 ▶ **a** Ionising radiation causes ionisation of a low-pressure gas inside the tube. The ionised gas allows a current to flow between two electrodes, and the current is detected by an electronic circuit.

b A rate meter gives an indication of the number of decays occurring per second.

c A bequerel is a rate of decay of one disintegration per second. 1 kBq is 1000 disintegrations per second.

3 ▶ **a** The half-life of a radioactive sample is the average time taken for half the unstable atoms in the sample to undergo radioactive decay.

b Random means that the decay of an individual atom is unpredictable; we cannot say when any particular atom will undergo decay.

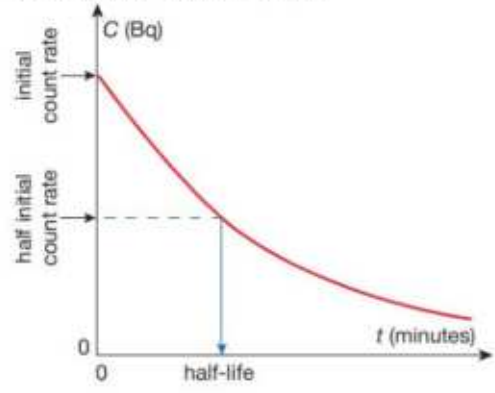
4 ▶ In 1.5 hours the sample has halved in activity three times (240 → 120 → 60 → 30) so three half-life periods have passed. The half-life is 30 minutes.

5 ▶ **a** 70 seconds (1 minute 10 seconds)

b $1\frac{3}{4}$ minutes is three half-lives (3 × 35 seconds), so the volume of water in the burette will have halved again. The burette will be one-eighth full, containing 6.25 ml.

6 ▶ **a** He should measure the background radiation. He should then use a GM tube and rate meter to measure the radioactivity of the sample at regular intervals of, say, 5 minutes for a period of 30–40 minutes.

b The readings of the activity of the sample should be corrected by subtracting the average background radiation count. The corrected readings should then be plotted on a graph of count rate against time. The time taken for the initial activity to fall to half can then be measured from the graph.



CHAPTER 19

1 ▶ **a** It has a short half-life, so its activity drops to a negligible level in a day or two. Beta particles and low energy gamma rays penetrate soft tissue easily, so the progress of the isotope through the body can be monitored easily. The emitted radiation is not strongly ionising, so the risk of tissue damage is acceptably small. (It is also relatively easy to produce.)

b By using a detector such as a GM tube.

2 ▶ β decay. The process involves a change in element – molybdenum to technetium – but with negligible change in mass – the mass number remains the same, 99.

3 ▶ a Iodine-131 is taken up by the thyroid gland in the same way as ordinary iodine. An overactive thyroid concentrates more iodine – if the concentration of I-131 is greater than normal, this can be detected by measuring the activity and comparing it with the expected take-up from a normal thyroid gland.

b I-131 is a high-energy beta-emitter. The radiation is sufficiently ionising to destroy cells in the thyroid, reducing its activity.

4 ▶ a Radioactive contamination is the accidental transfer of radioactive material onto or into an object or living organism. If safety procedures are ignored, people working with radioactive materials could be contaminated by radioactive materials.

Irradiation is the deliberate exposure to ionising radiation, such as gamma rays or X-rays. The irradiation lasts for a controlled period of time and is then turned off.

b Irradiation is used to sterilise surgical instruments. The instruments are sealed into wrappers and then irradiated with ionising radiation. The radiation passes through the wrapper, destroying any organisms on the instrument; the instrument then remains sterile within its wrapper. The process does not contaminate the instruments with radioactive material.

5 ▶ β radiation is used. It can pass through paper (unlike α particles) but the thicker the paper, the greater the amount of β radiation absorbed.

A β-emitting source is placed above the paper as it emerges from the rollers used to press it to the required thickness. A detector is placed beneath the paper in line with the source. The count rate will decrease if the thickness of the paper passing between the emitter and the detector increases.

To ensure accuracy, the background radiation count should be measured regularly so that the reading from the detector can be corrected. The half-life of the β-emitting source needs to be quite long, so the count rate does not fall significantly over short intervals. The apparatus will need to be recalibrated regularly using paper of known thickness.

Care should be taken to ensure workers cannot come within range of the radiation from the source. The source must be stored in a secure container that is lined with lead to ensure no ionising radiation can escape. The storage area and the part of the paper-making works in which the radiation source is being used should be clearly identified with standard signs. The source must be selected and screened to ensure that it emits only β radiation.

6 ▶ a Cosmic radiation causes C-14 to form from nitrogen in the atmosphere.

$$^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}p$$

b Carbon-14 has the same chemical behaviour as the abundant stable isotope C-12. Carbon reacts with oxygen to form carbon dioxide. Through photosynthesis, carbon-14 enters the food chain and therefore all living material.

c Once an organism is dead, no new C-14 is taken in via photosynthesis (plants) or food (animals). The proportion of C-14 in organic material decreases as the C-14 decays.

d The principal assumption is that the rate of production of C-14 through cosmic rays has remained constant over time. In practice this is not so, but it is possible to make adjustments for the variation in C-14 by taking samples from objects of known age.

e The half-life of C-14 is roughly 5600 years. After 10 half-lives have elapsed, the activity remaining in C-14 is too small for accurate measurement.

7 ▶ a $\frac{4.5 \times 10^9}{1600} = 2\,812\,500$ half-lives

b Student A is correct – radium formed when the Earth was formed would, by now, have decayed to an immeasurably small amount. Student B is incorrect, as the difference in the initial amount of radium would have to be immense. (As a model of this you can try folding a sheet of paper in half repeatedly – it becomes impossible after seven or eight folds, regardless of how large your starting sheet of paper is.) Student C is correct because radium is continuously being formed by the decay of isotopes of elements with very long half-lives.

8 ▶ a Alpha radiation has a very limited range. After alpha particles have travelled only a few centimetres in air, they have lost most of their kinetic energy and thus their ionising power. Alpha particles are stopped completely by quite thin layers of material, even if the material is not very dense.Thus alpha radiation is not particularly dangerous to living cells unless the source is very close to living tissue. If a source is very close to the skin it may, if the exposure is prolonged, cause burns and other tissue damage. The greatest danger is when alpha-emitting material is absorbed into the body. Inside the body, cells do not have the protection of a layer of skin and fat, so they are readily affected by the highly ionising alpha particles. This will result in cell destruction or mutation.

b Radon-220 is an alpha-emitter. It is a dense gas and therefore accumulates in the lower parts of buildings, etc. As it is a gas, it is readily inhaled and thus comes into close contact with internal cells. As described above, this is the most hazardous condition for alpha sources.

CHAPTER 20

1 ▶ a The nuclei of its atoms can be split apart by a nucleus.

b i A chain reaction is a reaction that produces further reactions. When a U-235 nucleus splits apart, the neutrons produced can cause further nuclei to split, and so on.

ii If there is only a small amount of U-235, neutrons can escape the material without hitting other U-235 nuclei.

2 ▶ Advantages: virtually inexhaustible supply of energy; does not produce 'greenhouse' gases.

Disadvantages: produces waste that remains extremely dangerous for thousands of years; very high set-up and decommissioning costs.

3 ▶ a Graphite acts as a moderator. It slows down the neutrons produced by the random decay of U-235 and this increases their ability to cause fission when they encounter other atoms of U-235.

b The control rods absorb neutrons. When they are raised out of the reactor, more neutrons are available to cause fission, so more fissions occur and more energy is transferred from nuclear mass into heat.

c The reactor is encased in several metres of concrete and this prevents nearly all radiation from escaping from the reactor vessel. Workers are also required to wear badges and carry electronic devices to monitor the total amount of exposure to radiation they have received over a period of time; these are checked regularly to ensure that workers do not exceed the recommended maximum safe exposure.

4 ▶ Nuclear fission is the splitting of large unstable atoms of isotopes of elements, like uranium, into smaller atoms and other particles, producing large amounts of energy.

Nuclear fusion occurs when atoms of light elements, such as hydrogen, are brought together with enough energy to make them combine to form heavier atoms such as helium.

5 ▶ Fission is a process that occurs naturally in isotopes of some elements. The fission process in a nuclear reactor is carefully controlled and can be shut down when energy is not required. The conditions for nuclear fusion to take place are much more difficult to create. Nuclei of the fusion elements, isotopes of hydrogen, need to be brought together in conditions of high density (lots of nuclei per cubic metre) and extremely high temperatures. These conditions occur in the hearts of stars but creating the conditions for a controlled fusion reaction on Earth is a huge challenge for scientists and engineers.

END OF UNIT 7 QUESTIONS

1 ▶ a D (1) **b** A (1) **c** B (1) **d** B (1) **e** C (1)

2 ▶ a ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + {}^{0}_{+1}\mathrm{e}$ (2) **b** ${}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He}$ (2)

c ${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + {}^{1}_{0}\mathrm{n}$ (3)

3 ▶ a E (1) **b** D (1) **c** A (1) **d** C (1) **e** B (1)

4 ▶ a i Nuclear fission is the splitting of large unstable atoms of isotopes of elements, such as uranium, into smaller atoms and other particles producing large amounts of energy. (4)

ii Nuclear fusion occurs when atoms of light elements, such as hydrogen, are brought together with enough energy to make them combine to form heavier atoms, such as helium. (4)

b i A chain reaction occurs when neutrons emitted from a nucleus of a fissile material (such as U-235) collide with further unstable nuclei, causing them to decay and emit further neutrons. If each decay triggers more than one further decay, the reaction will accelerate, causing a huge release of energy in a nuclear explosion. (4)

ii To control a chain reaction and slow down the rate at which decays occur and energy is released, it is necessary to reduce the number of emitted neutrons that could trigger further nuclei to decay. This is done by lowering control rods into the reactor core to absorb neutrons before they can collide with nuclei in the fissile fuel rods. When the control rods are fully lowered into the reactor core, the reaction is shut down and the rate of energy release is very small. (4)

5 ▶ a Nuclear fusion requires plasma made up of deuterium nuclei under high pressure raised to an extremely high temperature. Under these conditions, the nuclei have enough energy to overcome the electrostatic repulsion between them, so they can come into close contact and combine to form heavier nuclei of helium. (3)

b The nuclear fuel for fusion, an isotope of hydrogen, is in abundant supply in water. Uranium – the fuel for nuclear fission – is in limited supply and is dangerous to mine and transport because of its radioactivity. Fusion reactors produce no long-lived nuclear waste. (2)

6 ▶ a A is the atomic mass of the element, equal to the number of nucleons (protons and neutrons) in the nucleus (1). Z is the atomic number, equal to the number of protons in the nucleus (1).

b i D (1) **ii** B (1) **iii** A (1) **iv** C (1)

UNIT 8 ANSWERS

CHAPTER 21

1 ▶ a gravitational forces

b the mass and diameter of the planet

c The orbit of Mercury is much more curved than the orbit of Neptune because the gravitational forces between the Sun and Mercury are much stronger than those between Neptune and the Sun.

d The closer a comet is to the Sun, the faster it travels.

2 ▶ Moons orbit planets. Planets and comets orbit the Sun. The orbits of moons are circular. The orbits of planets are a little elongated (squashed circles or ellipses). The orbits of most comets are very elongated.

3 ▶ a orbital speed $= \frac{2\pi r}{T}$ so

$$T = \frac{2\pi r}{\text{speed}}$$

$$= \frac{2 \times \pi \times (35\,786 + 6400)\,\text{km}}{3.07}$$

$$= 86\,340\,\text{s}$$

b This is 24 hours, so the satellite completes one orbit in the same time as the Earth spins once. If the satellite is over the equator, it is in a geostationary orbit.

4 ▶ a 29.9 km/s (29 886 m/s)

b 12.4 km/s (12 452 m/s)

CHAPTER 22

1 ▶ **a** a galaxy
b attractive gravitational forces pull them together
c the Milky Way
d billions

2 ▶ **a** B class stars have a surface temperature of 33 000 – 10 000 K and a lot of the light they emit is in the blue part of the visible spectrum. K class stars have a surface temperature of 5200 – 3700 K and emit a lot of light in the orange / yellow part of the visible spectrum.
b M class
c F or G class
d 5200 – 7500 K

3 ▶ The apparent brightness of a star is a measure of how bright the star appears when seen from the Earth. The absolute brightness of a star is a measure of how bright the star would appear if it was placed 10 parsecs (32.6 light years) away from the Earth.

4 ▶ Clouds of particle are pulled together so strongly by gravity that nuclear reactions begin: the star is born. Forces of expansion due to the nuclear reactions and forces of contraction due to gravitational forces become balanced. The star is in its stable period. As the nuclear reactions between hydrogen nuclei become rarer, the forces become unbalanced. The star collapses and becomes very hot. New nuclear reactions begin and the star expands greatly until a new balance of forces is established. For stars much more massive than our Sun, the new star is called a red supergiant. At the end of this period, the forces become unbalanced once again and the star collapses. The collapse is so violent that the star becomes unstable and explodes. This is a supernova.

5 ▶ **a** A supernova is an exploding star.
b A supernova occurs when a very massive star (e.g. a red supergiant) reaches the end of this period. It collapses, becomes very unstable and explodes.

END OF UNIT 8 QUESTIONS

1 ▶ **a** B (1) **b** B (1) **c** D (1) **d** B (1)

2 ▶ comets (1); orbit (1); closest (1); Mercury (1); Venus (1); strongest (1); curved (1); furthest (1); Uranus (1); Neptune (1); weakest (1); curved (1); circular (1); elliptical (1); satellites (1); moons (1)

3 ▶ **a** $W = 80 \times 9 = 720\,\text{N}$ (3)
b $W = 80 \times 4 = 320\,\text{N}$ (3)
c $W = 80 \times 11 = 880\,\text{N}$ (3)

4 ▶ $V = \frac{2\pi r}{T} = \frac{2 \times \pi \times (250 \times 10^3 + 6400 \times 10^3)}{2 \times 60 \times 60}$

$= 5.8\,\text{km/s}$ (5)

5 ▶ **a** Mercury, Venus and Mars (1)
b 30 years (1)
c 1425 million kilometres (2)
d orbital speed $= \frac{2\pi r}{T}$

T in seconds $= 30 \times 365.25 \times 24 \times 60 \times 60$
$= 946\,728\,000\,\text{s}$

speed $= \frac{2 \times \pi \times 1\,425\,000\,000}{946\,728\,000} = 9.5\,\text{km/s}$ (3)

6 ▶ **a** Your diagram should show an ellipse (1), with the Sun near one end of it (1):



b As a comet gets closer to the Sun, the gravitational forces acting upon it increase (1) and it speeds up (1). As it travels away from the Sun, the Sun's gravity slows it down (1) so its speed is least when it is furthest from the Sun (1).

Proof That the Pandemic Was Planned & With Purpose



lymecoordinator56 3 months ago

https://principia-scientific.com/proof-that-the-pandemic-was-planned-with-purpose/

Proof That The Pandemic Was Planned & With Purpose

Published on September 30, 2020

Written by Dr James Fetzer



A group of over **500 medical doctors** in Germany called 'Doctors for Information' made a shocking statement during a national press conference: (1)

> **'The Corona panic is a play. It's a scam. A swindle. It's high time we understood that we're in the midst of a global crime.'**

This large group of medical experts publishes a medical newspaper on **500,000 copies every week,** to inform the public about the massive misinformation in the mainstream

media. They also organize mass protests in Europe, like the one on August 29, 2020 where **12 million people signed up** and several millions actually showed up.

Why do these 500+ medical doctors say the pandemic is a global crime? What do they know, that we don't?



Hundreds Of Spanish Medical Doctors Say The Pandemic Is Planned

In Spain a group of **600 medical doctors** called 'Doctors for Truth', made a similar statement during a press conference.



> **'Covid-19 is a false pandemic created for political purposes. This is a world dictatorship with a sanitary excuse. We urge doctors, the media and political authorities to stop this criminal operation, by spreading the truth.' (2)**

Germany and Spain are just two examples. Similar large groups of hundreds of medical experts exist in countries across the world.

In the USA a documentary called PLANDEMIC, which exposes COVID-19 as a criminal operation, is supported by over 27,000 medical doctors!

Why are these thousands of medical professionals worldwide saying the pandemic is a crime? What information do they have access to, that we are not getting from the mainstream media?

I invite you to look at the following facts with an open mind and then come to your own conclusions…

In 2015 A Testing Method Was Patented For… COVID-19

In 2015 a ‘System and Method for Testing for COVID-19’ was patented by Richard Rothschild, with a Dutch government organisation. Did you catch that? In 2015 – **four years before the disease even existed** – a testing method for COVID-19 was developed. (2B)

Take a deep breath and let that sink in for a while…

Millions Of COVID-19 Test Kits Sold In 2017 And 2018

As we know the new COVID-19 disease appeared in China towards the end of 2019. Therefore it was named COVID-19 which is an acronym for **Corona Virus Disease 2019.** Data from the World Integrated Trade Solution, however, shows something astonishing:

in 2017 and 2018 – two years before COVID-19 – hundreds of millions of test kits for COVID-19 were distributed worldwide.





‘Quick! Hide It!!’

This baffling data was discovered by someone on **September 5,** 2020, who posted it on social media. The next day it went viral all over the world. On **September 6** the WITS

suddenly changed the original designation ‘COVID-19’ into the vague ‘Medical Test Kits’.

This is not allowed in trade, because you always have to be specific. There are many types of test kits for different diseases.

The fact that they removed the specification ‘COVID-19’, after this data became known worldwide, **proves that they don’t want anyone to know about it.** They however forgot to delete one detail: the product code for these ‘Medical Test Kits’ is **300215 which means: ‘COVID-19 Test Kits’**



Their cover up came too late: this critical information was uncovered and is being revealed by millions worldwide. You can download a PDF that shows the original data of this website.

Two Years *Before* The Outbreak Of COVID-19 The USA, The EU, China And Nations Around The World Started Exporting Millions Of Diagnostic Test Instruments For… COVID-19, A Disease That Supposedly Didn’t Even Exist Back Then.

The COVID-19 ‘Project’ Is Planned Until 2025

The World Bank shows that COVID-19 is a project that is planned to continue until… **end of March 2025!** So the intention is to continue it for another **FIVE YEARS.** (2C)

Fauci Guaranteed A Pandemic Within The Next Two Years

In 2017 Anthony Fauci made a very strange prediction, with an even stranger certainty. With complete confidence Fauci announced that **during the first term of President Trump** a surprise outbreak of an infectious disease would surely happen. Here's what he said: (3)

> **There is NO QUESTION there is going to be a challenge for the coming administration in the arena of infectious diseases.**
>
> There will be a SURPRISE OUTBREAK.
> There's NO DOUBT in anyones mind about this.

How could Fauci guarantee a surprise outbreak to happen during the first term of the Trump administration? What did he know, that we don't?

> ‘In the next two years there will be a **SURPRISE OUTBREAK.** There’s **NO DOUBT** in anyones mind about this.’ **ANTHONY FAUCI**

Bill And Melinda Gates Guaranteed An Imminent Global Pandemic

---

In 2018 Bill Gates publicly announced that **a global pandemic was on it’s way** that could wipe out 30 million people. He said this would probably happen **during the next decade.** (4)

Melinda Gates added that an **engineered virus** is humanities greatest threat and also assured this would hit humanity **in the coming years.** (5)

Let their choice of words resound into your mind for a moment…

> ‘A global pandemic is **ON IT’S WAY.**
> An **ENGINEERED VIRUS** is humanities greatest threat.
> This will happen in the **NEXT DECADE.’ BILL AND MELINDA GATES**

They claim that the dense population of the world guarantees this imminent global pandemic. But let’s be honest: **most of the earth is uninhabited.** Just fly over America in an airplane and look out the window. You see empty space most of the time, with a few cities here and there. Most of the United States is still wide open and empty. The same goes for the rest of the world. Australia, Russia, India, China, America, Africa… **it’s wilderness for the most part.** Our planet isn’t nearly as populated as Bill Gates wants us to believe. This world map shows it clearly…

Most of the earth is totally void of any human presence. So the idea that the world is vastly overpopulated and is therefor bound to give rise to an imminent global pandemic is a lie.

The Gates also claimed that air travel was sure to create a global pandemic. But countless people have been traveling in airplanes the past century. Did that give rise to constant outbreaks of global pandemics? Of course not!

Their arguments why they **guaranteed** a global pandemic in the next few years are lies. So what is their real basis to make such guaranteed predictions?

Practicing For A Pandemic

A few months before the outbreak, Bill Gates – the world's nr 1 vaccine dealer – organized an event in New York City. Guess what the event was all about? It was a *'coronavirus pandemic exercise'*. Yes, you read that right:

Bill Gates organized a coronavirus pandemic exercise, right before it happened!

On the large display in the auditorium, you see the text printed: *'We need to prepare for the event that becomes a pandemic.'* This pandemic exercise was called Event201 and took place in October 2019, literally right before the outbreak.

Their conclusion was that all of humanity must be vaccinated…

The Purpose Of Event201 Was To Prepare The World For A Coronavirus Pandemic… Which Happened Right After The Event.

Excitement About Selling Vaccines In The Next Year

Shortly after this 'exercise for a coronavirus pandemic' Bill Gates tweeted:

> **I'm particularly excited about what the next year could mean for one of the best buys in global health: vaccines.**



Think about this: the world's nr 1 vaccine dealer guarantees a global pandemic to occur in the next few years, and his wife said we should all fear an engineered virus that is 'on its way'. Then they organize an exercise for an imminent global pandemic and say vaccines will be the only solution. Next Bill Gates tweets how excited he is about selling vaccines in the next year. Immediately after that, the announced pandemic breaks out.

Indeed, right away Bill Gates proclaims that the only solution for humanity is to buy his vaccines…

2020 Coronavirus Pandemic Predicted In 2013

Back in 2013 a musician wrote a song called PANDEMIC. In his lyrics he described a global pandemic that kills millions, shuts down economies and gives rise to riots.

His song literally described in great detail what we are seeing in our world today, seven years later.

He even mentioned *the exact year* of the pandemic: 2020, and the *specific type* of virus: a coronavirus. (6) This is a line in his lyrics from 2013:

> **'2020 combined with CoronaVirus, bodies stacking.'**

This song also predicted the riots that are now raging throughout America:

> **'The State is rioting, using the street outside. It's coming to your windows.'**

How could this musician have known in 2013 that a coronavirus pandemic would break out in 2020, and that during this pandemic riots would erupt? He explains:

> **'I Did Research Back In 2012, And Read The So Called "Conspiracy Theories". You Know, Those Investigations The Media Doesn't Want Us To Look Into. According To Those Theories Pandemics Were Bound To Happen In The Decade Of 2020 – 2030. So I Wrote The Song Pandemic About It.'**

'Get Ready For A Global Coronavirus Pandemic'

In September 2019 – also right before the outbreak – the Global Preparedness Monitoring Board released a report titled 'A World At Risk'.

It stressed the need to be prepared for… a coronavirus outbreak!

On the cover of the report is the picture of a coronavirus and people wearing face masks.

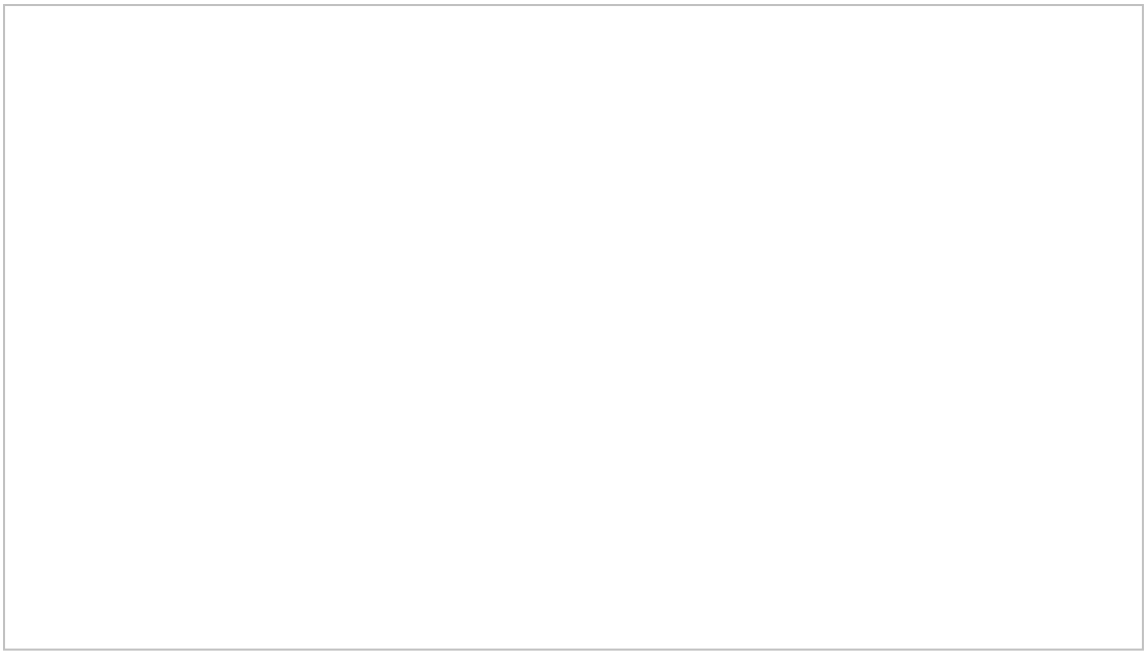
In the report we read the following interesting paragraph:

> **'The United Nations (including WHO) conducts at least two system-wide training and simulation exercises, including one for covering the deliberate release of a lethal respiratory pathogen.'**

Did you catch that?

They have been practicing for a *deliberate release of a lethal respiratory pathogen*.

Outbreak From China Announced



In 2018 The Institute for Disease Modeling made a video in which they show **a flu virus originating in China, from the area of Wuhan, and spreading all over the world**, killing millions. They called it 'A Simulation For A Global Flu Pandemic.' That is exactly what happened, two years later. Why did they say it would come from China? Why not Africa, where far more diseases are present? Or why not South America? Or India?

How could they know there would be a flu virus coming from China and even show Wuhan as the originating area, that would infect the whole world?

Was This Coronavirus Engineered?

Where did the virus come from? One of the world's leading experts in bioweapons is Dr. Francis Boyle. He is convinced it originated from a bioweapon lab in Wuhan, the Bio Safety Lab Level 4.

This facility is specialized in the development of… coronaviruses!

They take existing viruses and 'weaponize' them, meaning they make them far more dangerous, to be used as a biological weapon. In the following two minute video clip you see a spokesperson for the Trump administration, bioweapon expert Dr. Francis Boyle and president Trump talk about how this virus came from the lab in Wuhan.

Now comes the interesting part: in 2015 Anthony Fauci gave this very lab 3,7 million dollars.

Figure this: the same man who *guaranteed* a surprise outbreak of a virus in the next two years, gave almost 4 million dollars to a lab that develops coronaviruses. In the short clip below you can see a journalist ask president Trump about this grant given by Fauci to the Wuhan lab.

There are however more options in Wuhan where this virus could have originated from. Some believe it came from the Wuhan Virology Institute, where they also work on weaponizing coronaviruses.

Movies Predicted The Coronavirus Pandemic

Predictive programming is the process of informing the population about events that are soon to occur. The past years several movies and television series were produced, about… a global coronavirus pandemic!

The film 'Dead Plague' depicts a global pandemic with a coronavirus and even mentions hydroxychloroquine as the cure.

Another film called 'Contagion' shows how a coronavirus spreads globally with social distancing, face masks, lock-downs, washing of hands etc. as a result.

Literally everything we see now, is predicted in detail in these movies.

Pandemic Depicted During Olympics Summergames In 2012

Talking about predictive programming: during the opening show of the **Summer Olympics in 2012,** a coronavirus pandemic was played out for the eyes of the whole world. Dozens of hospital beds, large numbers of nurses becoming puppets of a controlling system, death lurking about, a demonic giant rising up over the world, and the whole theatre was lit up in such a way that seen from the sky it looked like a coronavirus.

Why did the Olympic Games show a coronavirus pandemic, in their opening show?

Worldwide Lockdown Predicted In 2008

The author and investigator Robin de Ruiter predicted in 2008 that there would come a global lockdown.

He said the purpose of this would be to create a new world of authoritarian control.

Because much of what he wrote back in 2008 is now happening right in front of our eyes, this book has been republished.

Journalists Predicted Planned Pandemic

In 2014 the investigative journalist **Harry Vox** predicted a planned global pandemic and said why the 'ruling class' would do such thing:

> **'They will stop at nothing to complete their toolkit of control. One of the things that had been missing from their toolkit is quarantines and curfews. The plan is to get hundreds of thousands of people infected with it and create the next phase of control.'** (7)

> ‘The plan is to get hundreds of thousands of people infected with it and **create the next phase of control.’ HARRY VOX, RENOWN INVESTIGATIVE JOURNALIST**

‘Scenario For The Future’

This renown researcher refers to a famous document by the Rockefeller Foundation in which everything we see happening now is literally predicted in great detail: the global pandemic, the lock-downs, the collapse of the economy and the imposing of authoritarian control.

It’s all described with terrifying accuracy… *ten years before it happened!*

The document is titled ‘Scenario for the Future of Technology and International Development’. (9) That says it all: **a scenario for the future.** It has a chapter called ‘LockStep’ in which a global pandemic is reported as if it happened in the past, but which is clearly intended as a rehearsal for the future.

The 2020 Pandemic Is Described In Horrifying Detail In The ‘Scenario For The Future’ By The Rockefeller Foundation Written In 2010.

The ‘Scenario for the Future’ continues with comparing two different responses to their predicted pandemic: the USA only ‘strongly discouraged’ people from flying, while China *enforced mandatory quarantine* for all citizens. The first response is accused of spreading the virus even more, while *the imposing of a suffocating lock-down* is praised. Then it goes on to describe the implementation of totalitarian control:

> **During the pandemic, national leaders around the world flexed their authority and imposed airtight rules and restrictions, from the mandatory wearing of face masks to body-temperature checks at the entries to communal spaces like train stations and supermarkets.**

Clearly the **flexing of authority** is the desired response. But it gets worse, according to this 'Scenario of the Future':

> **'Even after the pandemic faded, this more authoritarian control and oversight of citizens and their activities stuck and even intensified.'**

> **'In developed countries, this heightened oversight took many forms: biometric IDs for all citizens, for example, and tighter regulation of key industries whose stability was deemed vital to national interests.'**

According To The Rockefeller Foundation A Global Pandemic Must Result In Increased Control, Where People Gladly Surrender Their Freedom, In Order To Feel Safe Again

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Handbook For Global Control

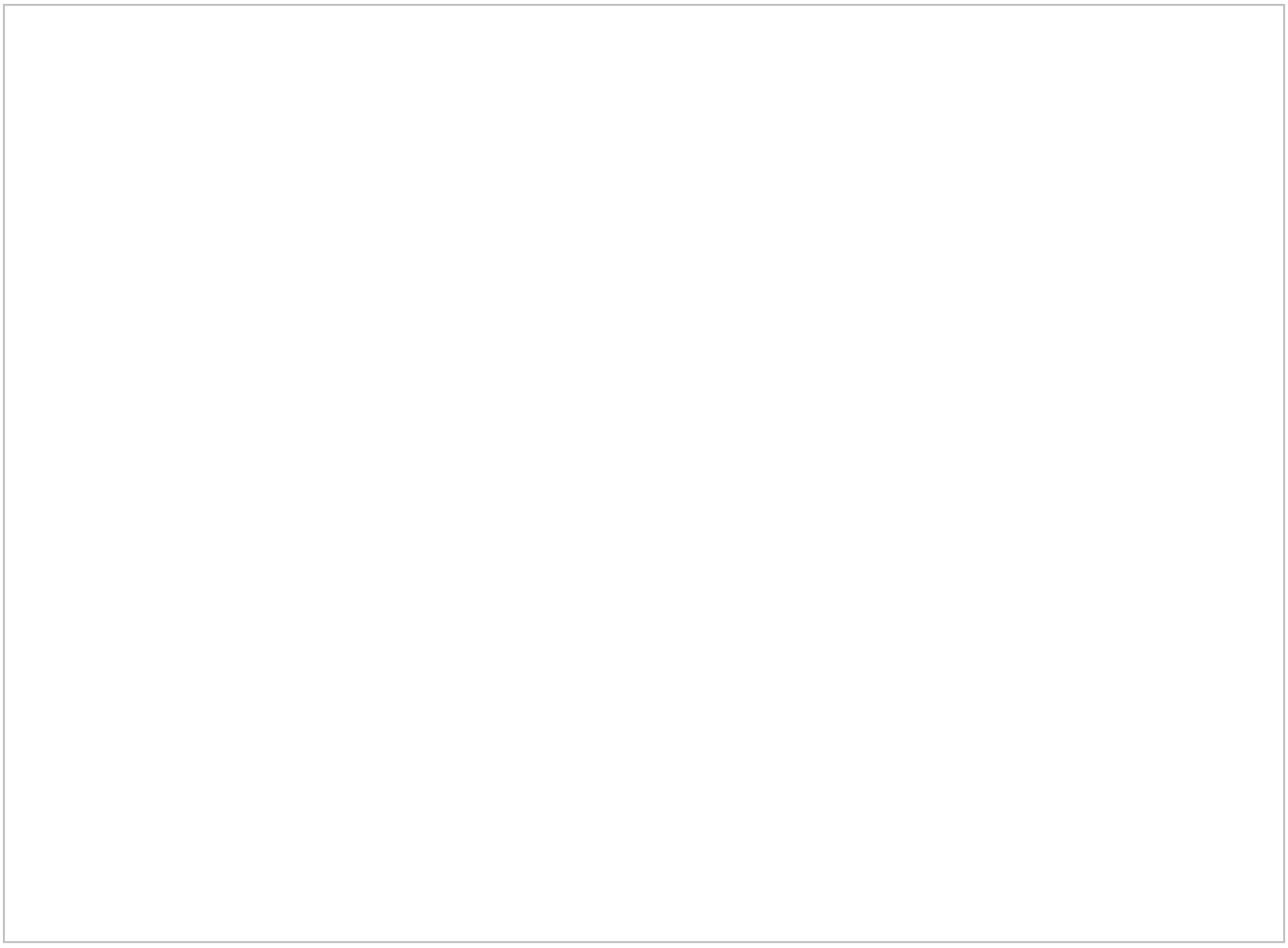
Now that the announced pandemic is indeed here, the same Rockefeller Foundation came forward with step two: **a handbook on how to implement new control systems during this pandemic.** Only when all the required control networks are in place, can the world open up again.

When you combine the two Rockefeller documents, you see the plan:

1) First they announce a global pandemic with a coronavirus and say what it should lead to: *a whole new level of authoritarian control.*

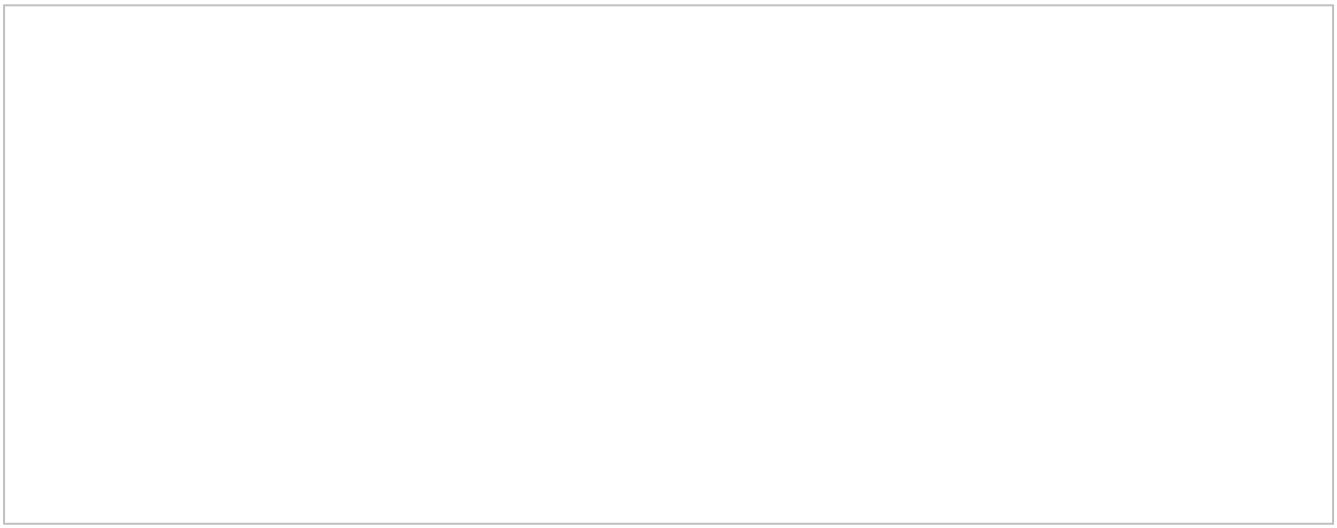
2) Secondly they give practical steps on how to apply this control system.

These are illustrations and quotes from their guide:



> **‘Digital apps and privacy-protected tracking software should be widely used to enable more complete contact tracking.’**

> **‘In order to fully control the Covid-19 epidemic, we need to test the majority of the population on a weekly basis.’**



According to their ‘Scenario of the future’ the entire world population should get a digital ID that indicates who has received all the vaccines. Without sufficient vaccinations, access to schools, concerts, churches, public transport etc. will be denied.

Now in 2020 that is exactly what Bill Gates and many governments are calling for.

Everyone’s Contacts Must Be Checked

In a leaked government video (10) we see a conversation between former American president **Bill Clinton and Andrew Cuomo**, the governor of the state of New York. They discuss how to set up a large control system to test the entire population and check all their contacts. They discuss how to build an army to carry out this control system.

> **‘Hundreds And Hundreds Of Control Agents Must Be Appointed. They Test Everyone And Then Check All Their Contacts. This Has Never Been Done Before On This Scale. This Is An Army Of Interrogators Who Will Check Everyone’s Contacts.’ ANDREW CUOMO, GOVERNOR OF NEW YORK**

A Whole New Level Of Global Control

Bill Gates also made it clear that only people who have been vaccinated against Covid-19 should be allowed to travel, go to school, attend meetings and work. (11) Digital vaccine ID's are already being developed (12) and **Gates has a patent on the technology** that makes it possible to trace an individual's body anywhere. This technology is called WO2020-060606 (13). In addition, Gates wants to set up a **global monitoring network,** which will track everyone who came into contact with Covid-19 (14).

The Plan: Inject Mankind With DNA Altering Vaccine

The famous investigative journalist **Anthony Patch** did years of research concerning the plans to control the world, by means of created pandemics and mandatory vaccines. During an interview in 2014 this researcher predicted the following:

> **'They will release a man-made coronavirus. As a result the people will demand a vaccine to protect them. This vaccine will add a third strain of DNA to a persons body, essentially making them a hybrid. Once a person is injected, almost immediately their DNA undergoes a transformation. This genetic change will cause people to loose the ability to think for themselves, without them even being aware this happened. Thus they can be controlled easier, to become slaves for the elite.'**

Of course that sounds insane and it is insane indeed. Yet we have to be aware that this professional investigator is no fool. He has done years of research and this is what he discovered over the years.

We Must Be Careful Not To Reject Sound Knowledge, Based On Years Of Research, Simply Because Of Our Own Lack Of Insight In These Topics.

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20 Years Of Research Says: The Vaccine Will Change Our DNA

Doctor Carrie Madej directed two large clinics in Georgia, before she went to the Dominican Republic to do humanitarian work. She studied DNA and vaccines for the past twenty years and made an urgent video in which she warns that there is a plan to inject humanity with very dangerous vaccines for Covid-19. The purpose of these new vaccines will be twofold:

1) reprogram our DNA and make us hybrids that are easier to control.
2) connect us to artificial intelligence through a digital vaccine ID, which will also open a whole new realm of control.

This medical expert says she has observed multiple times how diseases were spread over populations by air craft. Because of satefy reasons she is not able to share more details about this in public.

Depopulate The Earth By Means Of Organized Epidemics

Dr. John Coleman is a famous Intelligence Officer from the CIA who wrote a book titled 'The Committee of 300'. In it he explains how secret societies manipulate governments, health care, food industries, the media and so on. This book can be found on the website of the CIA. (15)

One of the primary goals of the many secret societies, that control governments and the media, is to depopulate the earth.

Dr. Coleman says the following about their strategy:

> ‘At least 4 billion useless eaters shall be eliminated by the year 2050 by means of limited wars and **organized epidemics of fatal rapid acting diseases**…’ **DR. JOHN COLEMAN, CIA INTELLIGENCE OFFICER**

Maintain Humanity Under 500,000,000

In 1980 a granite monument was erected in Georgia, called the Guidestones. A set of 10 guidelines is inscribed on the structure in eight modern languages and a shorter message is inscribed at the top of the structure in four ancient language scripts. The first guideline goes as follows:

> **1. Maintain humanity under 500,000,000 in perpetual balance with nature.**

The CIA officer Dr. Coleman revealed that one of their methods to 'maintain humanity' is to cause 'organized epidemics of fatal rapid acting diseases'.

Using Vaccines To Reduce Humanity

During a TED talk Bill Gates echoed this goal, when he literally said that new vaccines can be used to **reduce the world's population with 10 – 15%**! (16)

'There are now 6.7 billion people on earth and soon there will be 9 billion. However, we can reduce that number by ten to fifteen percent if we do a good job with new vaccines, health care and birth control'.

BILL GATES, VACCINE DEALER

Covid19 Vaccine For Population Control?

Mike Adams is a published food scientist, author of the popular science book Food Forensics and founder of ISO-accredited CWC Labs. Years ago he said the following:

> **An engineered bioweapon will be released in population centers. There will be calls for massive government funding for the vaccine industry to come up with a vaccine. Miraculously they will have a vaccine developed in record time. Everyone will be required to line up and take this vaccine shot.**

There is indeed a release of an engineered bioweapon, followed by a vaccine mandate, massive government funding for the vaccine industry and a vaccine that is being developed in record time.

The rest of his message is that this vaccine will slowly begin to kill millions – if not billions – of people over the course of a few years. It will be a kill-switch vaccine, designed to reduce the world's population.

SUMMARY: WAS THE PANDEMIC PLANNED?

Thousands of medical doctors call the pandemic a global crime, and a world dictatorship with a sanitary excuse.

Two years before Covid-19 came to the global scene, the European Union, the USA, China and other nations suddenly started exporting tens of millions of test kits for Covid-19.

In 2013 a musician predicts a global pandemic with a coronavirus and says this will happen in 2020. He knew this because of personal investigation of so called 'conspiracy theories'.

In 2017 Anthony Fauci *guaranteed* a surprise outbreak of an infectious disease during the first term of the Trump administration.

Right before the outbreak of a coronavirus pandemic, Bill Gates organized a global coronavirus pandemic exercise: Event201.

Right before the outbreak the Global Preparedness Monitoring Board told the world to be ready for a coronavirus pandemic.

In 2018 the Institute for Disease Modeling announced a global pandemic with a flu virus, originating in China in the area of Wuhan.

In 2018 Bill and Melinda Gates announced that in the coming years there would be a global pandemic of an engineered virus.

The coronavirus SARS-CoV-2 was created in the Bio Safety Lab Level 4 in Wuhan, which received millions of dollars from Anthony Fauci.

Several movies depicted the coronavirus pandemic with great detail, and even mention hydroxychloroquine as the cure.

The Summer Olympics in 2012 played a pandemic of a coronavirus during their opening show.

The investigative journalist Harry Vox predicted in 2014 that a global pandemic would be caused, so the 'ruling class' could implement a higher level of authoritarian control.

The investigative journalist Anthony Patch predicted a global pandemic with a man made virus, that would be used to force a DNA altering vaccine on humanity.

Dr. Carrie Madej studied DNA and vaccines for decades and says the plan is to use the Covid-19 vaccine to start the process of transhumanism: *reprogramming the human DNA*.

The CIA officer Dr. John Coleman studied secret societies and says their goal is to depopulate the earth by means of organized pandemics of fatal rapid acting diseases.

In the state of Georgia a huge monument was erected in 1980 with ten guidelines for humanity, in eight languages. The first of these 'Ten Commandments' is that humanity needs to be reduced to half a billion people.

Bill Gates said during a TED talk that new vaccines can be used to reduce the world's population with 10-15%.

The 'health ranger' Mike Adams predicted years ago what we see happening now: the release of an engineered bioweapon, followed by a vaccine mandate, massive government funding for the vaccine industry and a vaccine that is being developed in record time. He also predicted that this vaccine will kill innumerable people over the course of a couple of years.

In 2010 the Rockefeller Foundation published the 'Scenario for the future…' in which they describe a coming global pandemic, that should result in the implementation of authoritarian control over the people, which will then intensify after the pandemic.

In 2020 they publish a handbook on how to create this world of control, with a step by step guide. They say life cannot return back to normal, until the world has become 'Locked Down' with this top down control from authoritarian governments.

We indeed see that Bill Gates and many others worldwide are right away seizing control in unprecedented ways, with enforcing vaccine ID's, microchips that will be implanted into people, mandating the wearing of face masks, social distancing, forced lock-downs, extreme contact tracing, and so on.

Part of this top down control is extreme censoring of every single voice from doctors, scientists or other experts that criticize what is going on.

References

1: German group of Doctors For Information

2: Spanish group of Doctors For Truth

2B: Richard Rothshild patented a testing method for COVID-19 in 2015

2C: World Bank shows planned end date of project COVID-19

3: Fauci guarantees an outbreak with the next two years.

4: Bill Gates announced a global pandemic

5: Melinda Gates says humanities greatest threat is an engineered virus

6: Lyrics of 2013 song that predicted coronavirus pandemic in 2020

7: Harry Vox predicted the global pandemic

8: Robin de Ruiter predicted lockdowns

9: Scenario for the future described global pandemic

10: Andrew Cuomo talks with Bill Clinton about authoritarian control

11: Bill Gates talks about a digital ID to control people

12: Linking vaccines to a digital ID

13: Gates has pattent on technology to trace a body anywhere

14: Gates wants a global monitoring system

15: Download the book of CIA officer Coleman

16: Gates talks about reducing world population using vaccines

17: Tens of millions of Covid-19 test kist were exported by the EU, USA, China etc in 2017 and 2018

18: DAVOS and the gathering of the globalists

19: The head of the World Health Organization is member of violent terorrist group

20: Letter from archbishop and cardinals to humanity

Read more at jamesfetzer.org

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For **another detailed explanation of what's behind COVID-19:** https://articles.mercola.com/sites/articles/archive/2020/10/23/world-economic-forum-prediction-global-takeover

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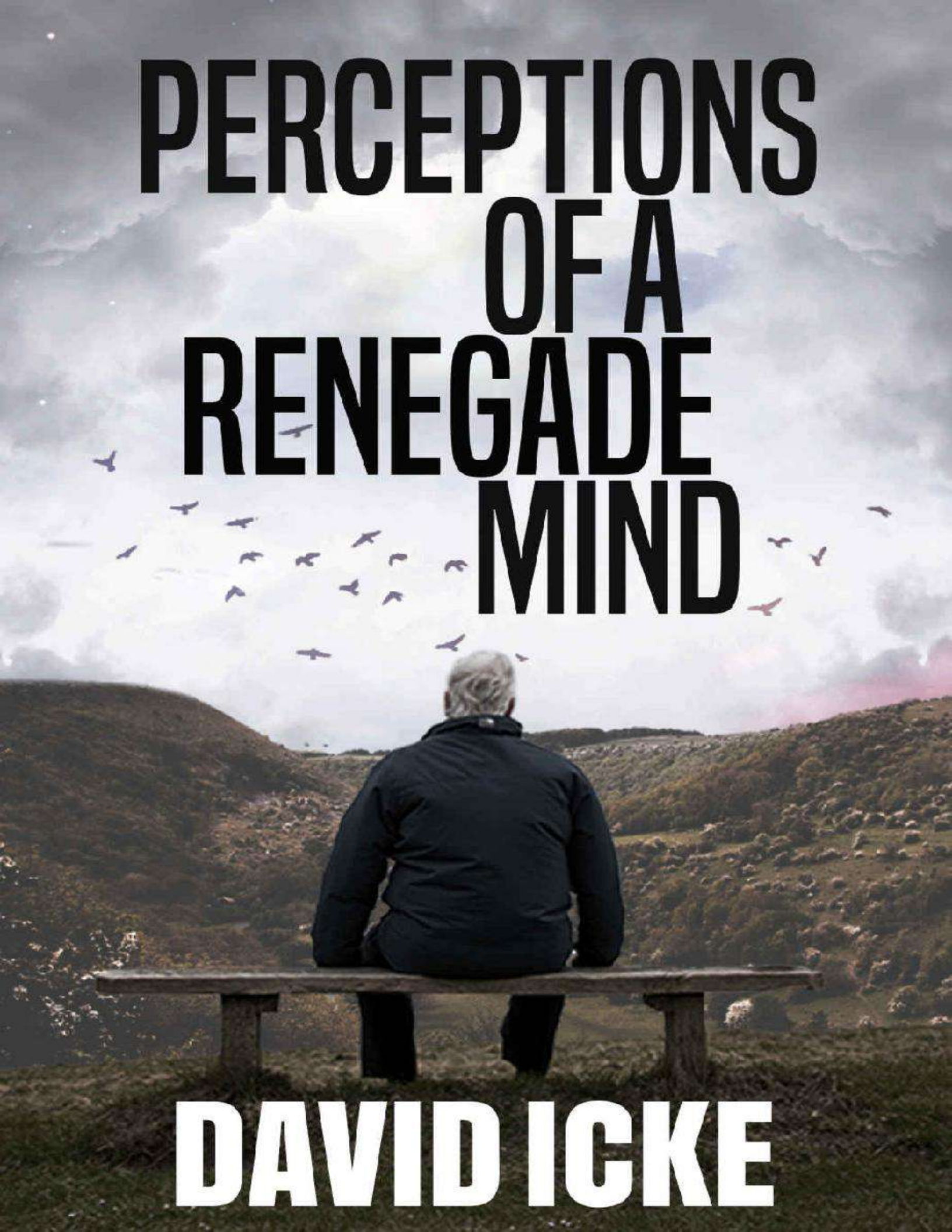
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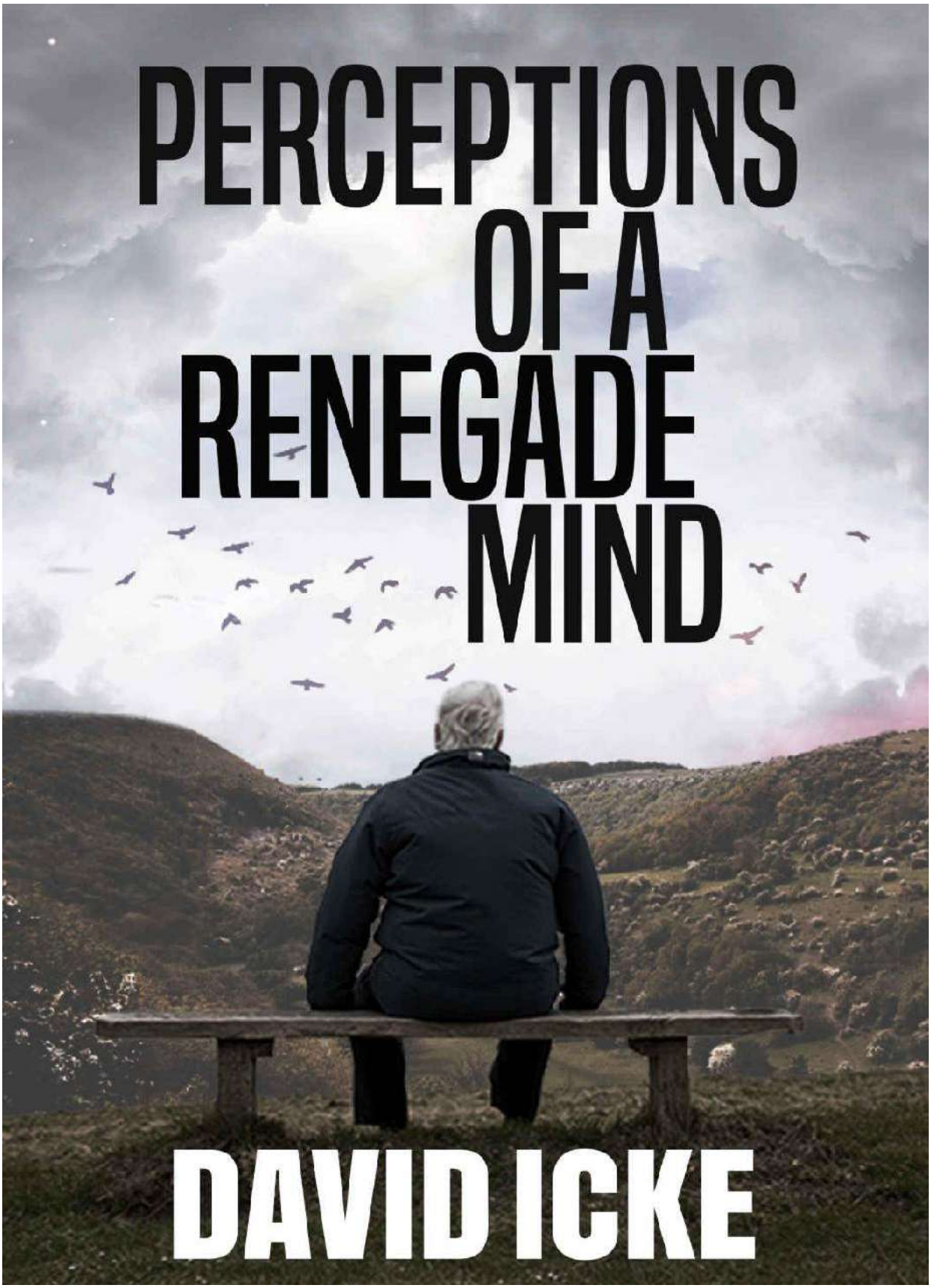
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Renegade:
Adjective
‘Having rejected tradition: Unconventional.’
Merriam-Webster Dictionary

Acquiescence to tyranny is the death of the spirit

You may be 38 years old, as I happen to be. And one day, some great opportunity stands before you and calls you to stand up for some great principle, some great issue, some great cause. And you refuse to do it because you are afraid … You refuse to do it because you want to live longer … You're afraid that you will lose your job, or you are afraid that you will be criticised or that you will lose your popularity, or you're afraid that somebody will stab you, or shoot at you or bomb your house; so you refuse to take the stand.

Well, you may go on and live until you are 90, but you're just as dead at 38 as you would be at 90. And the cessation of breathing in your life is but the belated announcement of an earlier death of the spirit.

Martin Luther King

How the few control the many and always have – the many do whatever they're told

'Forward, the Light Brigade!'
Was there a man dismayed?
Not though the soldier knew
Someone had blundered.
Theirs not to make reply,
Theirs not to reason why,
Theirs but to do and die.
Into the valley of Death
Rode the six hundred.

Cannon to right of them,
Cannon to left of them,
Cannon in front of them
Volleyed and thundered;
Stormed at with shot and shell,
Boldly they rode and well,
Into the jaws of Death,
Into the mouth of hell
Rode the six hundred

Alfred Lord Tennyson (1809-1892)

The mist is lifting slowly
I can see the way ahead
And I've left behind the empty streets
That once inspired my life
And the strength of the emotion
Is like thunder in the air
'Cos the promise that we made each other
Haunts me to the end

The secret of your beauty
And the mystery of your soul
I've been searching for in everyone I meet
And the times I've been mistaken
It's impossible to say
And the grass is growing
Underneath our feet

The words that I remember
From my childhood still are true
That there's none so blind
As those who will not see
And to those who lack the courage
And say it's dangerous to try
Well they just don't know
That love eternal will not be denied

I know you're out there somewhere
Somewhere, somewhere
I know you're out there somewhere

Somewhere you can hear my voice
I know I'll find you somehow
Somehow, somehow
I know I'll find you somehow
And somehow I'll return again to you

The Moody Blues

Are you a gutless wonder - or a Renegade Mind?

Monuments put from pen to paper,
Turns me into a gutless wonder,
And if you tolerate this,
Then your children will be next.
Gravity keeps my head down,
Or is it maybe shame ...

Manic Street Preachers

Rise like lions after slumber
In unvanquishable number.
Shake your chains to earth like dew
Which in sleep have fallen on you.
Ye are many – they are few.

Percy Shelley

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CHAPTER ONE

I'm thinking' – Oh, but *are* you?

Think for yourself and let others enjoy the privilege of doing so too
Voltaire

French-born philosopher, mathematician and scientist René Descartes became famous for his statement in Latin in the 17th century which translates into English as: 'I think, therefore I am.'

On the face of it that is true. Thought reflects perception and perception leads to both behaviour and self-identity. In that sense 'we' are what we think. But who or what is doing the thinking and is thinking the only route to perception? Clearly, as we shall see, 'we' are not always the source of 'our' perception, indeed with regard to humanity as a whole this is rarely the case; and thinking is far from the only means of perception. Thought is the village idiot compared with other expressions of consciousness that we all have the potential to access and tap into. This has to be true when we *are* those other expressions of consciousness which are infinite in nature. We have forgotten this, or, more to the point, been manipulated to forget.

These are not just the esoteric musings of the navel. The whole foundation of human control and oppression is control of perception. Once perception is hijacked then so is behaviour which is dictated by perception. Collective perception becomes collective behaviour and collective behaviour is what we call human society. Perception is all and those behind human control know that which is

why perception is the target 24/7 of the psychopathic manipulators that I call the Global Cult. They know that if they dictate perception they will dictate behaviour and collectively dictate the nature of human society. They are further aware that perception is formed from information received and if they control the circulation of information they will to a vast extent direct human behaviour. Censorship of information and opinion has become globally Nazi-like in recent years and never more blatantly than since the illusory 'virus pandemic' was triggered out of China in 2019 and across the world in 2020. Why have billions submitted to house arrest and accepted fascistic societies in a way they would have never believed possible? Those controlling the information spewing from government, mainstream media and Silicon Valley (all controlled by the same Global Cult networks) told them they were in danger from a 'deadly virus' and only by submitting to house arrest and conceding their most basic of freedoms could they and their families be protected. This monumental and provable lie became the *perception* of the billions and therefore the *behaviour* of the billions. In those few words you have the whole structure and modus operandi of human control. Fear is a perception – **F**alse **E**motion **A**ppearing **R**eal – and fear is the currency of control. In short … get them by the balls (or give them the impression that you have) and their hearts and minds will follow. Nothing grips the dangly bits and freezes the rear-end more comprehensively than fear.

World number 1

There are two 'worlds' in what appears to be one 'world' and the prime difference between them is knowledge. First we have the mass of human society in which the population is maintained in coldly-calculated ignorance through control of information and the 'education' (indoctrination) system. That's all you really need to control to enslave billions in a perceptual delusion in which what are perceived to be *their* thoughts and opinions are ever-repeated mantras that the system has been downloading all their lives through 'education', media, science, medicine, politics and academia

in which the personnel and advocates are themselves overwhelmingly the perceptual products of the same repetition. Teachers and academics in general are processed by the same programming machine as everyone else, but unlike the great majority they never leave the 'education' program. It gripped them as students and continues to grip them as programmers of subsequent generations of students. The programmed become the programmers – the programmed programmers. The same can largely be said for scientists, doctors and politicians and not least because as the American writer Upton Sinclair said: 'It is difficult to get a man to understand something when his salary depends upon his not understanding it.' If your career and income depend on thinking the way the system demands then you will – bar a few free-minded exceptions – concede your mind to the Perceptual Mainframe that I call the Postage Stamp Consensus. This is a tiny band of perceived knowledge and possibility 'taught' (downloaded) in the schools and universities, pounded out by the mainstream media and on which all government policy is founded. Try thinking, and especially speaking and acting, outside of the 'box' of consensus and see what that does for your career in the Mainstream Everything which bullies, harasses, intimidates and ridicules the population into compliance. Here we have the simple structure which enslaves most of humanity in a perceptual prison cell for an entire lifetime and I'll go deeper into this process shortly. Most of what humanity is taught as fact is nothing more than programmed belief. American science fiction author Frank Herbert was right when he said: 'Belief can be manipulated. Only knowledge is dangerous.' In the 'Covid' age belief is promoted and knowledge is censored. It was always so, but never to the extreme of today.

World number 2

A 'number 2' is slang for 'doing a poo' and how appropriate that is when this other 'world' is doing just that on humanity every minute of every day. World number 2 is a global network of secret societies and semi-secret groups dictating the direction of society via

governments, corporations and authorities of every kind. I have spent more than 30 years uncovering and exposing this network that I call the Global Cult and knowing its agenda is what has made my books so accurate in predicting current and past events. Secret societies are secret for a reason. They want to keep their hoarded knowledge to themselves and their chosen initiates and to hide it from the population which they seek through ignorance to control and subdue. The whole foundation of the division between World 1 and World 2 is *knowledge*. What number 1 knows number 2 must not. Knowledge they have worked so hard to keep secret includes (a) the agenda to enslave humanity in a centrally-controlled global dictatorship, and (b) the nature of reality and life itself. The latter (b) must be suppressed to allow the former (a) to prevail as I shall be explaining. The way the Cult manipulates and interacts with the population can be likened to a spider's web. The 'spider' sits at the centre in the shadows and imposes its will through the web with each strand represented in World number 2 by a secret society, satanic or semi-secret group, and in World number 1 – the world of the seen – by governments, agencies of government, law enforcement, corporations, the banking system, media conglomerates and Silicon Valley (Fig 1 overleaf). The spider and the web connect and coordinate all these organisations to pursue the same global outcome while the population sees them as individual entities working randomly and independently. At the level of the web governments *are* the banking system *are* the corporations *are* the media *are* Silicon Valley *are* the World Health Organization working from their inner cores as one unit. Apparently unconnected countries, corporations, institutions, organisations and people are on the *same team* pursuing the same global outcome. Strands in the web immediately around the spider are the most secretive and exclusive secret societies and their membership is emphatically restricted to the Cult inner-circle emerging through the generations from particular bloodlines for reasons I will come to. At the core of the core you would get them in a single room. That's how many people are dictating the direction of human society and its transformation

through the ‘Covid’ hoax and other means. As the web expands out from the spider we meet the secret societies that many people will be aware of – the Freemasons, Knights Templar, Knights of Malta, Opus Dei, the inner sanctum of the Jesuit Order, and such like. Note how many are connected to the Church of Rome and there is a reason for that. The Roman Church was established as a revamp, a rebranding, of the relocated ‘Church’ of Babylon and the Cult imposing global tyranny today can be tracked back to Babylon and Sumer in what is now Iraq.



Figure 1: The global web through which the few control the many. (Image Neil Hague.)

Inner levels of the web operate in the unseen away from the public eye and then we have what I call the cusp organisations located at the point where the hidden meets the seen. They include a series of satellite organisations answering to a secret society founded in London in the late 19th century called the Round Table and among them are the Royal Institute of International Affairs (UK, founded in 1920); Council on Foreign Relations (US, 1921); Bilderberg Group (worldwide, 1954); Trilateral Commission (US/worldwide, 1972); and the Club of Rome (worldwide, 1968) which was created to exploit environmental concerns to justify the centralisation of global power to ‘save the planet’. The Club of Rome instigated with others the human-caused climate change hoax which has led to all the ‘green

new deals' demanding that very centralisation of control. Cusp organisations, which include endless 'think tanks' all over the world, are designed to coordinate a single global policy between political and business leaders, intelligence personnel, media organisations and anyone who can influence the direction of policy in their own sphere of operation. Major players and regular attenders will know what is happening – or some of it – while others come and go and are kept overwhelmingly in the dark about the big picture. I refer to these cusp groupings as semi-secret in that they can be publicly identified, but what goes on at the inner-core is kept very much 'in house' even from most of their members and participants through a fiercely-imposed system of compartmentalisation. Only let them know what they need to know to serve your interests and no more. The structure of secret societies serves as a perfect example of this principle. Most Freemasons never get higher than the bottom three levels of 'degree' (degree of knowledge) when there are 33 official degrees of the Scottish Rite. Initiates only qualify for the next higher 'compartment' or degree if those at that level choose to allow them. Knowledge can be carefully assigned only to those considered 'safe'. I went to my local Freemason's lodge a few years ago when they were having an 'open day' to show how cuddly they were and when I chatted to some of them I was astonished at how little the rank and file knew even about the most ubiquitous symbols they use. The mushroom technique – keep them in the dark and feed them bullshit – applies to most people in the web as well as the population as a whole. Sub-divisions of the web mirror in theme and structure transnational corporations which have a headquarters somewhere in the world dictating to all their subsidiaries in different countries. Subsidiaries operate in their methodology and branding to the same centrally-dictated plan and policy in pursuit of particular ends. The Cult web functions in the same way. Each country has its own web as a subsidiary of the global one. They consist of networks of secret societies, semi-secret groups and bloodline families and their job is to impose the will of the spider and the global web in their particular country. Subsidiary networks control and manipulate the national political system, finance, corporations, media, medicine, etc. to

ensure that they follow the globally-dictated Cult agenda. These networks were the means through which the 'Covid' hoax could be played out with almost every country responding in the same way.

The 'Yessir' pyramid

Compartmentalisation is the key to understanding how a tiny few can dictate the lives of billions when combined with a top-down sequence of imposition and acquiescence. The inner core of the Cult sits at the peak of the pyramidal hierarchy of human society (Fig 2 overleaf). It imposes its will – its agenda for the world – on the level immediately below which acquiesces to that imposition. This level then imposes the Cult will on the level below them which acquiesces and imposes on the next level. Very quickly we meet levels in the hierarchy that have no idea there even is a Cult, but the sequence of imposition and acquiescence continues down the pyramid in just the same way. 'I don't know why we are doing this but the order came from "on-high" and so we better just do it.' Alfred Lord Tennyson said of the cannon fodder levels in his poem *The Charge of the Light Brigade*: 'Theirs not to reason why; theirs but to do and die.' The next line says that 'into the valley of death rode the six hundred' and they died because they obeyed without question what their perceived 'superiors' told them to do. In the same way the population capitulated to 'Covid'. The whole hierarchical pyramid functions like this to allow the very few to direct the enormous many. Eventually imposition-acquiescence-imposition-acquiescence comes down to the mass of the population at the foot of the pyramid. If they acquiesce to those levels of the hierarchy imposing on them (governments/law enforcement/doctors/media) a circuit is completed between the population and the handful of super-psychopaths in the Cult inner core at the top of the pyramid. Without a circuit-breaking refusal to obey, the sequence of imposition and acquiescence allows a staggeringly few people to impose their will upon the entirety of humankind. We are looking at the very sequence that has subjugated billions since the start of 2020. Our freedom has not been taken from us. Humanity has given it

away. Fascists do not impose fascism because there are not enough of them. Fascism is imposed by the population acquiescing to fascism. Put another way allowing their perceptions to be programmed to the extent that leads to the population giving their freedom away by giving their perceptions – their mind – away. If this circuit is not broken by humanity ceasing to cooperate with their own enslavement then nothing can change. For that to happen people have to critically think and see through the lies and window dressing and then summon the backbone to act upon what they see. The Cult spends its days working to stop either happening and its methodology is systematic and highly detailed, but it can be overcome and that is what this book is all about.

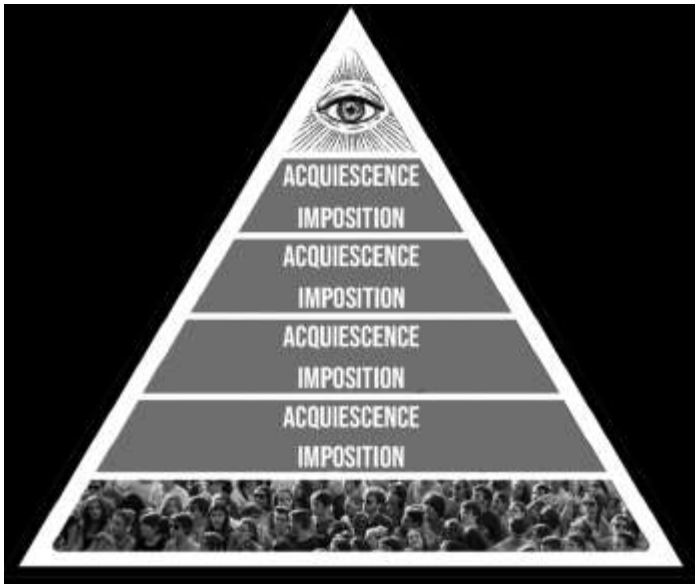


Figure 2: The simple sequence of imposition and compliance that allows a handful of people at the peak of the pyramid to dictate the lives of billions.

The Life Program

Okay, back to world number 1 or the world of the 'masses'. Observe the process of what we call 'life' and it is a perceptual download from cradle to grave. The Cult has created a global structure in which perception can be programmed and the program continually topped-up with what appears to be constant confirmation that the program is indeed true reality. The important word here is 'appears'.

This is the structure, the fly-trap, the Postage Stamp Consensus or Perceptual Mainframe, which represents that incredibly narrow band of perceived possibility delivered by the 'education' system, mainstream media, science and medicine. From the earliest age the download begins with parents who have themselves succumbed to the very programming their children are about to go through. Most parents don't do this out of malevolence and mostly it is quite the opposite. They do what they believe is best for their children and that is what the program has told them is best. Within three or four years comes the major transition from parental programming to full-blown state (Cult) programming in school, college and university where perceptually-programmed teachers and academics pass on their programming to the next generations. Teachers who resist are soon marginalised and their careers ended while children who resist are called a problem child for whom Ritalin may need to be prescribed. A few years after entering the 'world' children are under the control of authority figures representing the state telling them when they have to be there, when they can leave and when they can speak, eat, even go to the toilet. This is calculated preparation for a lifetime of obeying authority in all its forms. Reflex-action fear of authority is instilled by authority from the start. Children soon learn the carrot and stick consequences of obeying or defying authority which is underpinned daily for the rest of their life. Fortunately I daydreamed through this crap and never obeyed authority simply because it told me to. This approach to my alleged 'betters' continues to this day. There can be consequences of pursuing open-minded freedom in a world of closed-minded conformity. I spent a lot of time in school corridors after being ejected from the classroom for not taking some of it seriously and now I spend a lot of time being ejected from Facebook, YouTube and Twitter. But I can tell you that being true to yourself and not compromising your self-respect is far more exhilarating than bowing to authority for authority's sake. You don't have to be a sheep to the shepherd (authority) and the sheep dog (fear of not obeying authority).

The perceptual download continues throughout the formative years in school, college and university while script-reading 'teachers', 'academics' 'scientists', 'doctors' and 'journalists' insist that ongoing generations must be as programmed as they are. Accept the program or you will not pass your 'exams' which confirm your 'degree' of programming. It is tragic to think that many parents pressure their offspring to work hard at school to download the program and qualify for the next stage at college and university. The late, great, American comedian George Carlin said: 'Here's a bumper sticker I'd like to see: We are proud parents of a child who has resisted his teachers' attempts to break his spirit and bend him to the will of his corporate masters.' Well, the best of luck finding many of those, George. Then comes the moment to leave the formal programming years in academia and enter the 'adult' world of work. There you meet others in your chosen or prescribed arena who went through the same Postage Stamp Consensus program before you did. There is therefore overwhelming agreement between almost everyone on the basic foundations of Postage Stamp reality and the rejection, even contempt, of the few who have a mind of their own and are prepared to use it. This has two major effects. Firstly, the consensus confirms to the programmed that their download is really how things are. I mean, everyone knows that, right? Secondly, the arrogance and ignorance of Postage Stamp adherents ensure that anyone questioning the program will have unpleasant consequences for seeking their own truth and not picking their perceptions from the shelf marked: 'Things you must believe without question and if you don't you're a dangerous lunatic conspiracy theorist and a harebrained nutter'.

Every government, agency and corporation is founded on the same Postage Stamp prison cell and you can see why so many people believe the same thing while calling it their own 'opinion'. Fusion of governments and corporations in pursuit of the same agenda was the definition of fascism described by Italian dictator Benito Mussolini. The pressure to conform to perceptual norms downloaded for a lifetime is incessant and infiltrates society right

down to family groups that become censors and condemners of their own 'black sheep' for not, ironically, being sheep. We have seen an explosion of that in the 'Covid' era. Cult-owned global media unleashes its propaganda all day every day in support of the Postage Stamp and targets with abuse and ridicule anyone in the public eye who won't bend their mind to the will of the tyranny. Any response to this is denied (certainly in my case). They don't want to give a platform to expose official lies. Cult-owned-and-created Internet giants like Facebook, Google, YouTube and Twitter delete you for having an unapproved opinion. Facebook boasts that its AI censors delete 97-percent of 'hate speech' before anyone even reports it. Much of that 'hate speech' will simply be an opinion that Facebook and its masters don't want people to see. Such perceptual oppression is widely known as fascism. Even Facebook executive Benny Thomas, a 'CEO Global Planning Lead', said in comments secretly recorded by investigative journalism operation Project Veritas that Facebook is 'too powerful' and should be broken up:

I mean, no king in history has been the ruler of two billion people, but Mark Zuckerberg is … And he's 36. That's too much for a 36-year-old ... You should not have power over two billion people. I just think that's wrong.

Thomas said Facebook-owned platforms like Instagram, Oculus, and WhatsApp needed to be separate companies. 'It's too much power when they're all one together'. That's the way the Cult likes it, however. We have an executive of a Cult organisation in Benny Thomas that doesn't know there is a Cult such is the compartmentalisation. Thomas said that Facebook and Google 'are no longer companies, they're countries'. Actually they are more powerful than countries on the basis that if you control information you control perception and control human society.

I love my oppressor

Another expression of this psychological trickery is for those who realise they are being pressured into compliance to eventually

convince themselves to believe the official narratives to protect their self-respect from accepting the truth that they have succumbed to meek and subservient compliance. Such people become some of the most vehement defenders of the system. You can see them everywhere screaming abuse at those who prefer to think for themselves and by doing so reminding the compliers of their own capitulation to conformity. 'You are talking dangerous nonsense you Covidiot!!' Are you trying to convince me or yourself? It is a potent form of Stockholm syndrome which is defined as: 'A psychological condition that occurs when a victim of abuse identifies and attaches, or bonds, positively with their abuser.' An example is hostages bonding and even 'falling in love' with their kidnappers. The syndrome has been observed in domestic violence, abused children, concentration camp inmates, prisoners of war and many and various Satanic cults. These are some traits of Stockholm syndrome listed at goodtherapy.org:

- Positive regard towards perpetrators of abuse or captor [see 'Covid'].
- Failure to cooperate with police and other government authorities when it comes to holding perpetrators of abuse or kidnapping accountable [or in the case of 'Covid' cooperating with the police to enforce and defend their captors' demands].
- Little or no effort to escape [see 'Covid'].
- Belief in the goodness of the perpetrators or kidnappers [see 'Covid'].
- Appeasement of captors. This is a manipulative strategy for maintaining one's safety. As victims get rewarded – perhaps with less abuse or even with life itself – their appeasing behaviours are reinforced [see 'Covid'].
- Learned helplessness. This can be akin to 'if you can't beat 'em, join 'em'. As the victims fail to escape the abuse or captivity, they may start giving up and soon realize it's just easier for everyone if they acquiesce all their power to their captors [see 'Covid'].

- Feelings of pity toward the abusers, believing they are actually victims themselves. Because of this, victims may go on a crusade or mission to 'save' [protect] their abuser [see the venom unleashed on those challenging the official 'Covid' narrative].
- Unwillingness to learn to detach from their perpetrators and heal. In essence, victims may tend to be less loyal to themselves than to their abuser [*definitely* see 'Covid'].

Ponder on those traits and compare them with the behaviour of great swathes of the global population who have defended governments and authorities which have spent every minute destroying their lives and livelihoods and those of their children and grandchildren since early 2020 with fascistic lockdowns, house arrest and employment deletion to 'protect' them from a 'deadly virus' that their abusers' perceptually created to bring about this very outcome. We are looking at mass Stockholm syndrome. All those that agree to concede their freedom will believe those perceptions are originating in their own independent 'mind' when in fact by conceding their reality to Stockholm syndrome they have by definition conceded any independence of mind. Listen to the 'opinions' of the acquiescing masses in this 'Covid' era and what gushes forth is the repetition of the official version of everything delivered unprocessed, unfiltered and unquestioned. The whole programming dynamic works this way. I must be free because I'm told that I am and so I think that I am.

You can see what I mean with the chapter theme of 'I'm thinking – Oh, but *are* you?' The great majority are not thinking, let alone for themselves. They are repeating what authority has told them to believe which allows them to be controlled. Weaving through this mentality is the fear that the 'conspiracy theorists' are right and this again explains the often hysterical abuse that ensues when you dare to contest the official narrative of anything. Denial is the mechanism of hiding from yourself what you don't want to be true. Telling people what they want to hear is easy, but it's an infinitely greater challenge to tell them what they would rather not be happening.

One is akin to pushing against an open door while the other is met with vehement resistance no matter what the scale of evidence. I don't want it to be true so I'll convince myself that it's not. Examples are everywhere from the denial that a partner is cheating despite all the signs to the reflex-action rejection of any idea that world events in which country after country act in exactly the same way are centrally coordinated. To accept the latter is to accept that a force of unspeakable evil is working to destroy your life and the lives of your children with nothing too horrific to achieve that end. Who the heck wants that to be true? But if we don't face reality the end is duly achieved and the consequences are far worse and ongoing than breaking through the walls of denial today with the courage to make a stand against tyranny.

Connect the dots – but how?

A crucial aspect of perceptual programming is to portray a world in which everything is random and almost nothing is connected to anything else. Randomness cannot be coordinated by its very nature and once you perceive events as random the idea they could be connected is waved away as the rantings of the tinfoil-hat brigade. You can't plan and coordinate random you idiot! No, you can't, but you can hide the coldly-calculated and long-planned behind the *illusion* of randomness. A foundation manifestation of the Renegade Mind is to scan reality for patterns that connect the apparently random and turn pixels and dots into pictures. This is the way I work and have done so for more than 30 years. You look for similarities in people, modus operandi and desired outcomes and slowly, then ever quicker, the picture forms. For instance: There would seem to be no connection between the 'Covid pandemic' hoax and the human-caused global-warming hoax and yet they are masks (appropriately) on the same face seeking the same outcome. Those pushing the global warming myth through the Club of Rome and other Cult agencies are driving the lies about 'Covid' – Bill Gates is an obvious one, but they are endless. Why would the same people be involved in both when they are clearly not connected? Oh, but they

are. Common themes with personnel are matched by common goals. The 'solutions' to both 'problems' are centralisation of global power to impose the will of the few on the many to 'save' humanity from 'Covid' and save the planet from an 'existential threat' (we need 'zero Covid' and 'zero carbon emissions'). These, in turn, connect with the 'dot' of globalisation which was coined to describe the centralisation of global power in every area of life through incessant political and corporate expansion, trading blocks and superstates like the European Union. If you are the few and you want to control the many you have to centralise power and decision-making. The more you centralise power the more power the few at the centre will have over the many; and the more that power is centralised the more power those at the centre have to centralise even quicker. The momentum of centralisation gets faster and faster which is exactly the process we have witnessed. In this way the hoaxed 'pandemic' and the fakery of human-caused global warming serve the interests of globalisation and the seizure of global power in the hands of the Cult inner-circle which is behind 'Covid', 'climate change' *and* globalisation. At this point random 'dots' become a clear and obvious picture or pattern.

Klaus Schwab, the classic Bond villain who founded the Cult's Gates-funded World Economic Forum, published a book in 2020, *The Great Reset*, in which he used the 'problem' of 'Covid' to justify a total transformation of human society to 'save' humanity from 'climate change'. Schwab said: 'The pandemic represents a rare but narrow window of opportunity to reflect, reimagine, and reset our world.' What he didn't mention is that the Cult he serves is behind both hoaxes as I show in my book *The Answer*. He and the Cult don't have to reimagine the world. They know precisely what they want and that's why they destroyed human society with 'Covid' to 'build back better' in their grand design. Their job is not to imagine, but to get humanity to imagine and agree with their plans while believing it's all random. It must be pure coincidence that 'The Great Reset' has long been the Cult's code name for the global imposition of fascism and replaced previous code-names of the 'New World

Order' used by Cult frontmen like Father George Bush and the 'New Order of the Ages' which emerged from Freemasonry and much older secret societies. New Order of the Ages appears on the reverse of the Great Seal of the United States as 'Novus ordo seclorum' underneath the Cult symbol used since way back of the pyramid and all seeing-eye (Fig 3). The pyramid is the hierarchy of human control headed by the illuminated eye that symbolises the force behind the Cult which I will expose in later chapters. The term 'Annuit Coeptis' translates as 'He favours our undertaking'. We are told the 'He' is the Christian god, but 'He' is not as I will be explaining.



Figure 3: The all-seeing eye of the Cult 'god' on the Freemason-designed Great Seal of the United States and also on the dollar bill.

Having you on

Two major Cult techniques of perceptual manipulation that relate to all this are what I have called since the 1990s Problem-Reaction-Solution (PRS) and the Totalitarian Tiptoe (TT). They can be uncovered by the inquiring mind with a simple question: Who benefits? The answer usually identifies the perpetrators of a given action or happening through the concept of 'he who most benefits from a crime is the one most likely to have committed it'. The Latin 'Cue bono?' – Who benefits? – is widely attributed to the Roman orator and statesman Marcus Tullius Cicero. No wonder it goes back so far when the concept has been relevant to human behaviour since

history was recorded. Problem-Reaction-Solution is the technique used to manipulate us every day by covertly creating a problem (or the illusion of one) and offering the solution to the problem (or the illusion of one). In the first phase you create the problem and blame someone or something else for why it has happened. This may relate to a financial collapse, terrorist attack, war, global warming or pandemic, anything in fact that will allow you to impose the 'solution' to change society in the way you desire at that time. The 'problem' doesn't have to be real. PRS is manipulation of perception and all you need is the population to believe the problem is real. Human-caused global warming and the 'Covid pandemic' only have to be *perceived* to be real for the population to accept the 'solutions' of authority. I refer to this technique as NO-Problem-Reaction-Solution. Billions did not meekly accept house arrest from early 2020 because there was a real deadly 'Covid pandemic' but because they perceived – believed – that to be the case. The antidote to Problem-Reaction-Solution is to ask who benefits from the proposed solution. Invariably it will be anyone who wants to justify more control through deletion of freedom and centralisation of power and decision-making.

The two world wars were Problem-Reaction-Solutions that transformed and realigned global society. Both were manipulated into being by the Cult as I have detailed in books since the mid-1990s. They dramatically centralised global power, especially World War Two, which led to the United Nations and other global bodies thanks to the overt and covert manipulations of the Rockefeller family and other Cult bloodlines like the Rothschilds. The UN is a stalking horse for full-blown world government that I will come to shortly. The land on which the UN building stands in New York was donated by the Rockefellers and the same Cult family was behind Big Pharma scalpel and drug 'medicine' and the creation of the World Health Organization as part of the UN. They have been stalwarts of the eugenics movement and funded Hitler's race-purity expert' Ernst Rudin. The human-caused global warming hoax has been orchestrated by the Club of Rome through the UN which is

manufacturing both the 'problem' through its Intergovernmental Panel on Climate Change and imposing the 'solution' through its Agenda 21 and Agenda 2030 which demand the total centralisation of global power to 'save the world' from a climate hoax the United Nations is itself perpetrating. What a small world the Cult can be seen to be particularly among the inner circles. The bedfellow of Problem-Reaction-Solution is the Totalitarian Tiptoe which became the Totalitarian Sprint in 2020. The technique is fashioned to hide the carefully-coordinated behind the cover of apparently random events. You start the sequence at 'A' and you know you are heading for 'Z'. You don't want people to know that and each step on the journey is presented as a random happening while all the steps strung together lead in the same direction. The speed may have quickened dramatically in recent times, but you can still see the incremental approach of the Tiptoe in the case of 'Covid' as each new imposition takes us deeper into fascism. Tell people they have to do this or that to get back to 'normal', then this and this and this. With each new demand adding to the ones that went before the population's freedom is deleted until it disappears. The spider wraps its web around the flies more comprehensively with each new diktat. I'll highlight this in more detail when I get to the 'Covid' hoax and how it has been pulled off. Another prime example of the Totalitarian Tiptoe is how the Cult-created European Union went from a 'free-trade zone' to a centralised bureaucratic dictatorship through the Tiptoe of incremental centralisation of power until nations became mere administrative units for Cult-owned dark suits in Brussels.

The antidote to ignorance is knowledge which the Cult seeks vehemently to deny us, but despite the systematic censorship to that end the Renegade Mind can overcome this by vociferously seeking out the facts no matter the impediments put in the way. There is also a method of thinking and perceiving – *knowing* – that doesn't even need names, dates, place-type facts to identify the patterns that reveal the story. I'll get to that in the final chapter. All you need to know about the manipulation of human society and to what end is still out there – *at the time of writing* – in the form of books, videos

and websites for those that really want to breach the walls of programmed perception. To access this knowledge requires the abandonment of the mainstream media as a source of information in the awareness that this is owned and controlled by the Cult and therefore promotes mass perceptions that suit the Cult. Mainstream media lies all day, every day. That is its function and very reason for being. Where it does tell the truth, here and there, is only because the truth and the Cult agenda very occasionally coincide. If you look for fact and insight to the BBC, CNN and virtually all the rest of them you are asking to be conned and perceptually programmed.

Know the outcome and you'll see the journey

Events seem random when you have no idea where the world is being taken. Once you do the random becomes the carefully planned. Know the outcome and you'll see the journey is a phrase I have been using for a long time to give context to daily happenings that appear unconnected. Does a problem, or illusion of a problem, trigger a proposed 'solution' that further drives society in the direction of the outcome? Invariably the answer will be yes and the random – *abracadabra* – becomes the clearly coordinated. So what is this outcome that unlocks the door to a massively expanded understanding of daily events? I will summarise its major aspects – the fine detail is in my other books – and those new to this information will see that the world they thought they were living in is a very different place. The foundation of the Cult agenda is the incessant centralisation of power and all such centralisation is ultimately in pursuit of Cult control on a global level. I have described for a long time the planned world structure of top-down dictatorship as the Hunger Games Society. The term obviously comes from the movie series which portrayed a world in which a few living in military-protected hi-tech luxury were the overlords of a population condemned to abject poverty in isolated 'sectors' that were not allowed to interact. 'Covid' lockdowns and travel bans anyone? The 'Hunger Games' pyramid of structural control has the inner circle of the Cult at the top with pretty much the entire

population at the bottom under their control through dependency for survival on the Cult. The whole structure is planned to be protected and enforced by a military-police state (Fig 4).

Here you have the reason for the global lockdowns of the fake pandemic to coldly destroy independent incomes and livelihoods and make everyone dependent on the 'state' (the Cult that controls the 'states'). I have warned in my books for many years about the plan to introduce a 'guaranteed income' – a barely survivable pittance – designed to impose dependency when employment was destroyed by AI technology and now even more comprehensively at great speed by the 'Covid' scam. Once the pandemic was played and lockdown consequences began to delete independent income the authorities began to talk right on cue about the need for a guaranteed income and a 'Great Reset'. Guaranteed income will be presented as benevolent governments seeking to help a desperate people – desperate as a direct result of actions of the same governments. The truth is that such payments are a trap. You will only get them if you do exactly what the authorities demand including mass vaccination (genetic manipulation). We have seen this theme already in Australia where those dependent on government benefits have them reduced if parents don't agree to have their children vaccinated according to an insane health-destroying government-dictated schedule. Calculated economic collapse applies to governments as well as people. The Cult wants rid of countries through the creation of a world state with countries broken up into regions ruled by a world government and super states like the European Union. Countries must be bankrupted, too, to this end and it's being achieved by the trillions in 'rescue packages' and furlough payments, trillions in lost taxation, and money-no-object spending on 'Covid' including constant all-medium advertising (programming) which has made the media dependent on government for much of its income. The day of reckoning is coming – as planned – for government spending and given that it has been made possible by printing money and not by production/taxation there is inflation on the way that has the

potential to wipe out monetary value. In that case there will be no need for the Cult to steal your money. It just won't be worth anything (see the German Weimar Republic before the Nazis took over). Many have been okay with lockdowns while getting a percentage of their income from so-called furlough payments without having to work. Those payments are dependent, however, on people having at least a theoretical job with a business considered non-essential and ordered to close. As these business go under because they are closed by lockdown after lockdown the furlough stops and it will for everyone eventually. Then what? The 'then what?' is precisely the idea.



Figure 4: The Hunger Games Society structure I have long warned was planned and now the 'Covid' hoax has made it possible. This is the real reason for lockdowns.

Hired hands

Between the Hunger Games Cult elite and the dependent population is planned to be a vicious military-police state (a fusion of the two into one force). This has been in the making for a long time with police looking ever more like the military and carrying weapons to match. The pandemic scam has seen this process accelerate so fast as

lockdown house arrest is brutally enforced by carefully recruited fascist minds and gormless system-servers. The police and military are planned to merge into a centrally-directed world army in a global structure headed by a world government which wouldn't be elected even by the election fixes now in place. The world army is not planned even to be human and instead wars would be fought, primarily against the population, using robot technology controlled by artificial intelligence. I have been warning about this for decades and now militaries around the world are being transformed by this very AI technology. The global regime that I describe is a particular form of fascism known as a technocracy in which decisions are not made by clueless and co-opted politicians but by unelected technocrats – scientists, engineers, technologists and bureaucrats. Cult-owned-and-controlled Silicon Valley giants are examples of technocracy and they already have far more power to direct world events than governments. They are with their censorship *selecting* governments. I know that some are calling the 'Great Reset' a Marxist communist takeover, but fascism and Marxism are different labels for the same tyranny. Tell those who lived in fascist Germany and Stalinist Russia that there was a difference in the way their freedom was deleted and their lives controlled. I could call it a fascist technocracy or a Marxist technocracy and they would be equally accurate. The Hunger Games society with its world government structure would oversee a world army, world central bank and single world cashless currency imposing its will on a microchipped population (Fig 5). Scan its different elements and see how the illusory pandemic is forcing society in this very direction at great speed. Leaders of 23 countries and the World Health Organization (WHO) backed the idea in March, 2021, of a global treaty for 'international cooperation' in 'health emergencies' and nations should 'come together as a global community for peaceful cooperation that extends beyond this crisis'. Cut the Orwellian bullshit and this means another step towards global government. The plan includes a cashless digital money system that I first warned about in 1993. Right at the start of 'Covid' the deeply corrupt Tedros

Adhanom Ghebreyesus, the crooked and merely gofer 'head' of the World Health Organization, said it was possible to catch the 'virus' by touching cash and it was better to use cashless means. The claim was ridiculous nonsense and like the whole 'Covid' mind-trick it was nothing to do with 'health' and everything to do with pushing every aspect of the Cult agenda. As a result of the Tedros lie the use of cash has plummeted. The Cult script involves a single world digital currency that would eventually be technologically embedded in the body. China is a massive global centre for the Cult and if you watch what is happening there you will know what is planned for everywhere. The Chinese government is developing a digital currency which would allow fines to be deducted immediately via AI for anyone caught on camera breaking its fantastic list of laws and the money is going to be programmable with an expiry date to ensure that no one can accrue wealth except the Cult and its operatives.



Figure 5: The structure of global control the Cult has been working towards for so long and this has been enormously advanced by the 'Covid' illusion.

Serfdom is so smart

The Cult plan is far wider, extreme, and more comprehensive than even most conspiracy researchers appreciate and I will come to the true depths of deceit and control in the chapters 'Who controls the

Cult?' and 'Escaping Wetiko'. Even the world that we know is crazy enough. We are being deluged with ever more sophisticated and controlling technology under the heading of 'smart'. We have smart televisions, smart meters, smart cards, smart cars, smart driving, smart roads, smart pills, smart patches, smart watches, smart skin, smart borders, smart pavements, smart streets, smart cities, smart communities, smart environments, smart growth, smart planet ... smart *everything* around us. Smart technologies and methods of operation are designed to interlock to create a global Smart Grid connecting the entirety of human society including human minds to create a centrally-dictated 'hive' mind. 'Smart cities' is code for densely-occupied megacities of total surveillance and control through AI. Ever more destructive frequency communication systems like 5G have been rolled out without any official testing for health and psychological effects (colossal). 5G/6G/7G systems are needed to run the Smart Grid and each one becomes more destructive of body and mind. Deleting independent income is crucial to forcing people into these AI-policed prisons by ending private property ownership (except for the Cult elite). The Cult's Great Reset now openly foresees a global society in which no one will own any possessions and everything will be rented while the Cult would own literally everything under the guise of government and corporations. The aim has been to use the lockdowns to destroy sources of income on a mass scale and when the people are destitute and in unrepayable amounts of debt (problem) Cult assets come forward with the pledge to write-off debt in return for handing over all property and possessions (solution). Everything – literally everything including people – would be connected to the Internet via AI. I was warning years ago about the coming Internet of Things (IoT) in which all devices and technology from your car to your fridge would be plugged into the Internet and controlled by AI. Now we are already there with much more to come. The next stage is the Internet of Everything (IoE) which is planned to include the connection of AI to the human brain and body to replace the human mind with a centrally-controlled AI mind. Instead of perceptions

being manipulated through control of information and censorship those perceptions would come direct from the Cult through AI. What do you think? You think whatever AI decides that you think. In human terms there would be no individual 'think' any longer. Too incredible? The ravings of a lunatic? Not at all. Cult-owned crazies in Silicon Valley have been telling us the plan for years without explaining the real motivation and calculated implications. These include Google executive and 'futurist' Ray Kurzweil who highlights the year 2030 for when this would be underway. He said:

Our thinking ... will be a hybrid of biological and non-biological thinking ... humans will be able to extend their limitations and 'think in the cloud' ... We're going to put gateways to the cloud in our brains ... We're going to gradually merge and enhance ourselves ... In my view, that's the nature of being human – we transcend our limitations.

As the technology becomes vastly superior to what we are then the small proportion that is still human gets smaller and smaller and smaller until it's just utterly negligible.

The sales-pitch of Kurzweil and Cult-owned Silicon Valley is that this would make us 'super-human' when the real aim is to make us post-human and no longer 'human' in the sense that we have come to know. The entire global population would be connected to AI and become the centrally-controlled 'hive-mind' of externally-delivered perceptions. The Smart Grid being installed to impose the Cult's will on the world is being constructed to allow particular locations – even one location – to control the whole global system. From these prime control centres, which absolutely include China and Israel, anything connected to the Internet would be switched on or off and manipulated at will. Energy systems could be cut, communication via the Internet taken down, computer-controlled driverless autonomous vehicles driven off the road, medical devices switched off, the potential is limitless given how much AI and Internet connections now run human society. We have seen nothing yet if we allow this to continue. Autonomous vehicle makers are working with law enforcement to produce cars designed to automatically pull over if they detect a police or emergency vehicle flashing from up to 100 feet away. At a police stop the car would be unlocked and the

window rolled down automatically. Vehicles would only take you where the computer (the state) allowed. The end of petrol vehicles and speed limiters on all new cars in the UK and EU from 2022 are steps leading to electric computerised transport over which ultimately you have no control. The picture is far bigger even than the Cult global network or web and that will become clear when I get to the nature of the 'spider'. There is a connection between all these happenings and the instigation of DNA-manipulating 'vaccines' (which aren't 'vaccines') justified by the 'Covid' hoax. That connection is the unfolding plan to transform the human body from a biological to a synthetic biological state and this is why synthetic biology is such a fast-emerging discipline of mainstream science. 'Covid vaccines' are infusing self-replicating synthetic genetic material into the cells to cumulatively take us on the Totalitarian Tiptoe from Human 1.0 to the synthetic biological Human 2.0 which will be physically and perceptually attached to the Smart Grid to one hundred percent control every thought, perception and deed. Humanity needs to wake up and *fast*.

This is the barest explanation of where the 'outcome' is planned to go but it's enough to see the journey happening all around us. Those new to this information will already see 'Covid' in a whole new context. I will add much more detail as we go along, but for the minutiae evidence see my mega-works, *The Answer, The Trigger* and *Everything You Need to Know But Have Never Been Told*.

Now – how does a Renegade Mind see the 'world'?

CHAPTER TWO

Renegade Perception

It is one thing to be clever and another to be wise
George R.R. Martin

A simple definition of the difference between a programmed mind and a Renegade Mind would be that one sees only dots while the other connects them to see the picture. Reading reality with accuracy requires the observer to (a) know the planned outcome and (b) realise that everything, but *everything*, is connected.

The entirety of infinite reality is connected – that's its very nature – and with human society an expression of infinite reality the same must apply. Simple cause and effect is a connection. The effect is triggered by the cause and the effect then becomes the cause of another effect. Nothing happens in isolation because it *can't*. Life in whatever reality is simple choice and consequence. We make choices and these lead to consequences. If we don't like the consequences we can make different choices and get different consequences which lead to other choices and consequences. The choice and the consequence are not only connected they are indivisible. You can't have one without the other as an old song goes. A few cannot control the world unless those being controlled allow that to happen – cause and effect, choice and consequence. Control – who has it and who doesn't – is a two-way process, a symbiotic relationship, involving the controller and controlled. 'They took my freedom away!!' Well, yes, but you also gave it to them. Humanity is

subjected to mass control because humanity has acquiesced to that control. This is all cause and effect and literally a case of give and take. In the same way world events of every kind are connected and the Cult works incessantly to sell the illusion of the random and coincidental to maintain the essential (to them) perception of dots that hide the picture. Renegade Minds know this and constantly scan the world for patterns of connection. This is absolutely pivotal in understanding the happenings in the world and without that perspective clarity is impossible. First you know the planned outcome and then you identify the steps on the journey – the day-by-day apparently random which, when connected in relation to the outcome, no longer appear as individual events, but as the proverbial *chain* of events leading in the same direction. I'll give you some examples:

Political puppet show

We are told to believe that politics is 'adversarial' in that different parties with different beliefs engage in an endless tussle for power. There may have been some truth in that up to a point – and only a point – but today divisions between 'different' parties are rhetorical not ideological. Even the rhetorical is fusing into one-speak as the parties eject any remaining free thinkers while others succumb to the ever-gathering intimidation of anyone with the 'wrong' opinion. The Cult is not a new phenomenon and can be traced back thousands of years as my books have documented. Its intergenerational initiates have been manipulating events with increasing effect the more that global power has been centralised. In ancient times the Cult secured control through the system of monarchy in which 'special' bloodlines (of which more later) demanded the right to rule as kings and queens simply by birthright and by vanquishing others who claimed the same birthright. There came a time, however, when people had matured enough to see the unfairness of such tyranny and demanded a say in who governed them. Note the word – *governed* them. Not served them – *governed* them, hence government defined as 'the political direction and control exercised over the

actions of the members, citizens, or inhabitants of communities, societies, and states; direction of the affairs of a state, community, etc.' Governments exercise control over rather than serve just like the monarchies before them. Bizarrely there are still countries like the United Kingdom which are ruled by a monarch *and* a government that officially answers to the monarch. The UK head of state and that of Commonwealth countries such as Canada, Australia and New Zealand is 'selected' by who in a *single family* had unprotected sex with whom and in what order. Pinch me it can't be true. Ouch! Shit, it is. The demise of monarchies in most countries offered a potential vacuum in which some form of free and fair society could arise and the Cult had that base covered. Monarchies had served its interests but they couldn't continue in the face of such widespread opposition and, anyway, replacing a 'royal' dictatorship that people could see with a dictatorship 'of the people' hiding behind the concept of 'democracy' presented far greater manipulative possibilities and ways of hiding coordinated tyranny behind the illusion of 'freedom'.

Democracy is quite wrongly defined as government selected by the population. This is not the case at all. It is government selected by *some* of the population (and then only in theory). This 'some' doesn't even have to be the majority as we have seen so often in first-past-the-post elections in which the so-called majority party wins fewer votes than the 'losing' parties combined. Democracy can give total power to a party in government from a minority of the votes cast. It's a sleight of hand to sell tyranny as freedom. Seventy-four million Trump-supporting Americans didn't vote for the 'Democratic' Party of Joe Biden in the distinctly dodgy election in 2020 and yet far from acknowledging the wishes and feelings of that great percentage of American society the Cult-owned Biden government set out from day one to destroy them and their right to a voice and opinion. Empty shell Biden and his Cult handlers said they were doing this to 'protect democracy'. Such is the level of lunacy and sickness to which politics has descended. Connect the dots and relate them to the desired outcome – a world government run by self-appointed technocrats and no longer even elected

politicians. While operating through its political agents in government the Cult is at the same time encouraging public distain for politicians by putting idiots and incompetents in theoretical power on the road to deleting them. The idea is to instil a public reaction that says of the technocrats: 'Well, they couldn't do any worse than the pathetic politicians.' It's all about controlling perception and Renegade Minds can see through that while programmed minds cannot when they are ignorant of both the planned outcome and the manipulation techniques employed to secure that end. This knowledge can be learned, however, and fast if people choose to get informed.

Politics may at first sight appear very difficult to control from a central point. I mean look at the 'different' parties and how would you be able to oversee them all and their constituent parts? In truth, it's very straightforward because of their structure. We are back to the pyramid of imposition and acquiescence. Organisations are structured in the same way as the system as a whole. Political parties are not open forums of free expression. They are hierarchies. I was a national spokesman for the British Green Party which claimed to be a different kind of politics in which influence and power was devolved; but I can tell you from direct experience – and it's far worse now – that Green parties are run as hierarchies like all the others however much they may try to hide that fact or kid themselves that it's not true. A very few at the top of all political parties are directing policy and personnel. They decide if you are elevated in the party or serve as a government minister and to do that you have to be a yes man or woman. Look at all the maverick political thinkers who never ascended the greasy pole. If you want to progress within the party or reach 'high-office' you need to fall into line and conform. Exceptions to this are rare indeed. Should you want to run for parliament or Congress you have to persuade the local or state level of the party to select you and for that you need to play the game as dictated by the hierarchy. If you secure election and wish to progress within the greater structure you need to go on conforming to what is acceptable to those running the hierarchy

from the peak of the pyramid. Political parties are perceptual gulags and the very fact that there are party 'Whips' appointed to 'whip' politicians into voting the way the hierarchy demands exposes the ridiculous idea that politicians are elected to serve the people they are supposed to represent. Cult operatives and manipulation has long seized control of major parties that have any chance of forming a government and at least most of those that haven't. A new party forms and the Cult goes to work to infiltrate and direct. This has reached such a level today that you see video compilations of 'leaders' of all parties whether Democrats, Republicans, Conservative, Labour and Green parroting the same Cult mantra of 'Build Back Better' and the 'Great Reset' which are straight off the Cult song-sheet to describe the transformation of global society in response to the Cult-instigated hoaxes of the 'Covid pandemic' and human-caused 'climate change'. To see Caroline Lucas, the Green Party MP that I knew when I was in the party in the 1980s, speaking in support of plans proposed by Cult operative Klaus Schwab representing the billionaire global elite is a real head-shaker.

Many parties – one master

The party system is another mind-trick and was instigated to change the nature of the dictatorship by swapping 'royalty' for dark suits that people believed – though now ever less so – represented their interests. Understanding this trick is to realise that a single force (the Cult) controls all parties either directly in terms of the major ones or through manipulation of perception and ideology with others. You don't need to manipulate Green parties to demand your transformation of society in the name of 'climate change' when they are obsessed with the lie that this is essential to 'save the planet'. You just give them a platform and away they go serving your interests while believing they are being environmentally virtuous. America's political structure is a perfect blueprint for how the two or multi-party system is really a one-party state. The Republican Party is controlled from one step back in the shadows by a group made up of billionaires and their gofers known as neoconservatives or Neocons.

I have exposed them in fine detail in my books and they were the driving force behind the policies of the imbecilic presidency of Boy George Bush which included 9/11 (see *The Trigger* for a comprehensive demolition of the official story), the subsequent 'war on terror' (war *of* terror) and the invasions of Afghanistan and Iraq. The latter was a No-Problem-Reaction-Solution based on claims by Cult operatives, including Bush and British Prime Minister Tony Blair, about Saddam Hussein's 'weapons of mass destruction' which did not exist as war criminals Bush and Blair well knew.

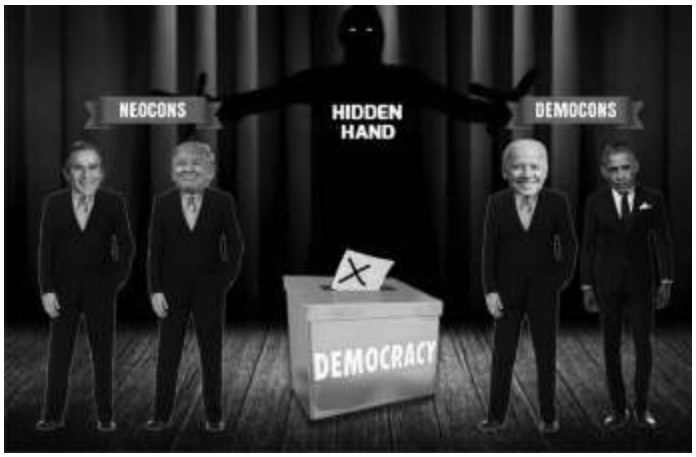


Figure 6: Different front people, different parties – same control system.

The Democratic Party has its own 'Neocon' group controlling from the background which I call the 'Democons' and here's the penny-drop – the Neocons and Democons answer to the same masters one step further back into the shadows (Fig 6). At that level of the Cult the Republican and Democrat parties are controlled by the same people and no matter which is in power the Cult is in power. This is how it works in almost every country and certainly in Britain with Conservative, Labour, Liberal Democrat and Green parties now all on the same page whatever the rhetoric may be in their feeble attempts to appear different. Neocons operated at the time of Bush through a think tank called The Project for the New American Century which in September, 2000, published a document entitled *Rebuilding America's Defenses: Strategies, Forces, and Resources*

For a New Century demanding that America fight 'multiple, simultaneous major theatre wars' as a 'core mission' to force regime-change in countries including Iraq, Libya and Syria. Neocons arranged for Bush ('Republican') and Blair ('Labour Party') to front-up the invasion of Iraq and when they departed the Democons orchestrated the targeting of Libya and Syria through Barack Obama ('Democrat') and British Prime Minister David Cameron ('Conservative Party'). We have 'different' parties and 'different' people, but the same unfolding script. The more the Cult has seized the reigns of parties and personnel the more their policies have transparently pursued the same agenda to the point where the fascist 'Covid' impositions of the Conservative junta of Jackboot Johnson in Britain were opposed by the Labour Party because they were not fascist enough. The Labour Party is likened to the US Democrats while the Conservative Party is akin to a British version of the Republicans and on both sides of the Atlantic they all speak the same language and support the direction demanded by the Cult although some more enthusiastically than others. It's a similar story in country after country because it's all centrally controlled. Oh, but what about Trump? I'll come to him shortly. Political 'choice' in the 'party' system goes like this: You vote for Party A and they get into government. You don't like what they do so next time you vote for Party B and they get into government. You don't like what they do when it's pretty much the same as Party A and why wouldn't that be with both controlled by the same force? Given that only two, sometimes three, parties have any chance of forming a government to get rid of Party B that you don't like you have to vote again for Party A which … you don't like. This, ladies and gentlemen, is what they call 'democracy' which we are told – wrongly – is a term interchangeable with 'freedom'.

The cult of cults

At this point I need to introduce a major expression of the Global Cult known as Sabbatian-Frankism. Sabbatian is also spelt as Sabbatean. I will summarise here. I have published major exposés

and detailed background in other works. Sabbatian-Frankism combines the names of two frauds posing as 'Jewish' men, Sabbatai Zevi (1626-1676), a rabbi, black magician and occultist who proclaimed he was the Jewish messiah; and Jacob Frank (1726-1791), the Polish 'Jew', black magician and occultist who said he was the reincarnation of 'messiah' Zevi and biblical patriarch Jacob. They worked across two centuries to establish the Sabbatian-Frankist cult that plays a major, indeed central, role in the manipulation of human society by the Global Cult which has its origins much further back in history than Sabbatai Zevi. I should emphasise two points here in response to the shrill voices that will scream 'anti-Semitism': (1) Sabbatian-Frankists are NOT Jewish and only pose as such to hide their cult behind a Jewish façade; and (2) my information about this cult has come from Jewish sources who have long realised that their society and community has been infiltrated and taken over by interloper Sabbatian-Frankists. Infiltration has been the foundation technique of Sabbatian-Frankism from its official origin in the 17th century. Zevi's Sabbatian sect attracted a massive following described as the biggest messianic movement in Jewish history, spreading as far as Africa and Asia, and he promised a return for the Jews to the 'Promised Land' of Israel. Sabbatianism was not Judaism but an inversion of everything that mainstream Judaism stood for. So much so that this sinister cult would have a feast day when Judaism had a fast day and whatever was forbidden in Judaism the Sabbatians were encouraged and even commanded to do. This included incest and what would be today called Satanism. Members were forbidden to marry outside the sect and there was a system of keeping their children ignorant of what they were part of until they were old enough to be trusted not to unknowingly reveal anything to outsiders. The same system is employed to this day by the Global Cult in general which Sabbatian-Frankism has enormously influenced and now largely controls.

Zevi and his Sabbatians suffered a setback with the intervention by the Sultan of the Islamic Ottoman Empire in the Middle East and what is now the Republic of Turkey where Zevi was located. The

Sultan gave him the choice of proving his 'divinity', converting to Islam or facing torture and death. Funnily enough Zevi chose to convert or at least appear to. Some of his supporters were disillusioned and drifted away, but many did not with 300 families also converting – only in theory – to Islam. They continued behind this Islamic smokescreen to follow the goals, rules and rituals of Sabbatianism and became known as 'crypto-Jews' or the 'Dönmeh' which means 'to turn'. This is rather ironic because they didn't 'turn' and instead hid behind a fake Islamic persona. The process of appearing to be one thing while being very much another would become the calling card of Sabbatianism especially after Zevi's death and the arrival of the Satanist Jacob Frank in the 18th century when the cult became Sabbatian-Frankism and plumbed still new depths of depravity and infiltration which included – still includes – human sacrifice and sex with children. Wherever Sabbatians go paedophilia and Satanism follow and is it really a surprise that Hollywood is so infested with child abuse and Satanism when it was established by Sabbatian-Frankists and is still controlled by them? Hollywood has been one of the prime vehicles for global perceptual programming and manipulation. How many believe the version of 'history' portrayed in movies when it is a travesty and inversion (again) of the truth? Rabbi Marvin Antelman describes Frankism in his book, *To Eliminate the Opiate*, as 'a movement of complete evil' while Jewish professor Gershom Scholem said of Frank in *The Messianic Idea in Judaism*: 'In all his actions [he was] a truly corrupt and degenerate individual ... one of the most frightening phenomena in the whole of Jewish history.' Frank was excommunicated by traditional rabbis, as was Zevi, but Frank was undeterred and enjoyed vital support from the House of Rothschild, the infamous banking dynasty whose inner-core are Sabbatian-Frankists and not Jews. Infiltration of the Roman Church and Vatican was instigated by Frank with many Dönmeh 'turning' again to convert to Roman Catholicism with a view to hijacking the reins of power. This was the ever-repeating modus operandi and continues to be so. Pose as an advocate of the religion, culture or country that you want to control and then

manipulate your people into the positions of authority and influence largely as advisers, administrators and Svengalis for those that appear to be in power. They did this with Judaism, Christianity (Christian Zionism is part of this), Islam and other religions and nations until Sabbatian-Frankism spanned the world as it does today.

Sabbatian Saudis and the terror network

One expression of the Sabbatian-Frankist Dönmeh within Islam is the ruling family of Saudi Arabia, the House of Saud, through which came the vile distortion of Islam known as Wahhabism. This is the violent creed followed by terrorist groups like Al-Qaeda and ISIS or Islamic State. Wahhabism is the hand-chopping, head-chopping 'religion' of Saudi Arabia which is used to keep the people in a constant state of fear so the interloper House of Saud can continue to rule. Al-Qaeda and Islamic State were lavishly funded by the House of Saud while being created and directed by the Sabbatian-Frankist network in the United States that operates through the Pentagon, CIA and the government in general of whichever 'party'. The front man for the establishment of Wahhabism in the middle of the 18th century was a Sabbatian-Frankist 'crypto-Jew' posing as Islamic called Muhammad ibn Abd al-Wahhab. His daughter would marry the son of Muhammad bin Saud who established the first Saudi state before his death in 1765 with support from the British Empire. Bin Saud's successors would establish modern Saudi Arabia in league with the British and Americans in 1932 which allowed them to seize control of Islam's major shrines in Mecca and Medina. They have dictated the direction of Sunni Islam ever since while Iran is the major centre of the Shiite version and here we have the source of at least the public conflict between them. The Sabbatian network has used its Wahhabi extremists to carry out Problem-Reaction-Solution terrorist attacks in the name of 'Al-Qaeda' and 'Islamic State' to justify a devastating 'war on terror', ever-increasing surveillance of the population and to terrify people into compliance. Another insight of the Renegade Mind is the streetwise understanding that

just because a country, location or people are attacked doesn't mean that those apparently representing that country, location or people are not behind the attackers. Often they are *orchestrating* the attacks because of the societal changes that can be then justified in the name of 'saving the population from terrorists'.

I show in great detail in *The Trigger* how Sabbatian-Frankists were the real perpetrators of 9/11 and not '19 Arab hijackers' who were blamed for what happened. Observe what was justified in the name of 9/11 alone in terms of Middle East invasions, mass surveillance and control that fulfilled the demands of the Project for the New American Century document published by the Sabbatian Neocons. What appear to be enemies are on the deep inside players on the same Sabbatian team. Israel and Arab 'royal' dictatorships are all ruled by Sabbatians and the recent peace agreements between Israel and Saudi Arabia, the United Arab Emirates (UAE) and others are only making formal what has always been the case behind the scenes. Palestinians who have been subjected to grotesque tyranny since Israel was bombed and terrorised into existence in 1948 have never stood a chance. Sabbatian-Frankists have controlled Israel (so the constant theme of violence and war which Sabbatians love) and they have controlled the Arab countries that Palestinians have looked to for real support that never comes. 'Royal families' of the Arab world in Saudi Arabia, Bahrain, UAE, etc., are all Sabbatians with allegiance to the aims of the cult and not what is best for their Arabic populations. They have stolen the oil and financial resources from their people by false claims to be 'royal dynasties' with a genetic right to rule and by employing vicious militaries to impose their will.

Satanic 'illumination'

The Satanist Jacob Frank formed an alliance in 1773 with two other Sabbatians, Mayer Amschel Rothschild (1744-1812), founder of the Rothschild banking dynasty, and Jesuit-educated fraudulent Jew, Adam Weishaupt, and this led to the formation of the Bavarian Illuminati, firstly under another name, in 1776. The Illuminati would

be the manipulating force behind the French Revolution (1789-1799) and was also involved in the American Revolution (1775-1783) before and after the Illuminati's official creation. Weishaupt would later become (in public) a Protestant Christian in archetypal Sabbatian style. I read that his name can be decoded as Adam-Weishaupt or 'the first man to lead those who know'. He wasn't a leader in the sense that he was a subordinate, but he did lead those below him in a crusade of transforming human society that still continues today. The theme was confirmed as early as 1785 when a horseman courier called Lanz was reported to be struck by lighting and extensive Illuminati documents were found in his saddlebags. They made the link to Weishaupt and detailed the plan for world takeover. Current events with 'Covid' fascism have been in the making for a very long time. Jacob Frank was jailed for 13 years by the Catholic Inquisition after his arrest in 1760 and on his release he headed for Frankfurt, Germany, home city and headquarters of the House of Rothschild where the alliance was struck with Mayer Amschel Rothschild and Weishaupt. Rothschild arranged for Frank to be given the title of Baron and he became a wealthy nobleman with a big following of Jews in Germany, the Austro-Hungarian Empire and other European countries. Most of them would have believed he was on their side.

The name 'Illuminati' came from the Zohar which is a body of works in the Jewish mystical 'bible' called the Kabbalah. 'Zohar' is the foundation of Sabbatian-Frankist belief and in Hebrew 'Zohar' means 'splendour', 'radiance', 'illuminated', and so we have 'Illuminati'. They claim to be the 'Illuminated Ones' from their knowledge systematically hidden from the human population and passed on through generations of carefully-chosen initiates in the global secret society network or Cult. Hidden knowledge includes an awareness of the Cult agenda for the world and the nature of our collective reality that I will explore later. Cult 'illumination' is symbolised by the torch held by the Statue of Liberty which was gifted to New York by French Freemasons in Paris who knew exactly what it represents. 'Liberty' symbolises the goddess worshipped in

Babylon as Queen Semiramis or Ishtar. The significance of this will become clear. Notice again the ubiquitous theme of inversion with the Statue of 'Liberty' really symbolising mass control (Fig 7). A mirror-image statute stands on an island in the River Seine in Paris from where New York Liberty originated (Fig 8). A large replica of the Liberty flame stands on top of the Pont de l'Alma tunnel in Paris where Princess Diana died in a Cult ritual described in *The Biggest Secret*. Lucifer 'the light bringer' is related to all this (and much more as we'll see) and 'Lucifer' is a central figure in Sabbatian-Frankism and its associated Satanism. Sabbatians reject the Jewish Torah, or Pentateuch, the 'five books of Moses' in the Old Testament known as Genesis, Exodus, Leviticus, Numbers, and Deuteronomy which are claimed by Judaism and Christianity to have been dictated by 'God' to Moses on Mount Sinai. Sabbatians say these do not apply to them and they seek to replace them with the Zohar to absorb Judaism and its followers into their inversion which is an expression of a much greater global inversion. They want to delete all religions and force humanity to worship a one-world religion – Sabbatian Satanism that also includes worship of the Earth goddess. Satanic themes are being more and more introduced into mainstream society and while Christianity is currently the foremost target for destruction the others are planned to follow.



Figure 7: The Cult goddess of Babylon disguised as the Statue of Liberty holding the flame of Lucifer the 'light bringer'.



Figure 8: Liberty's mirror image in Paris where the New York version originated.

Marx brothers

Rabbi Marvin Antelman connects the Illuminati to the Jacobins in *To Eliminate the Opiate* and Jacobins were the force behind the French Revolution. He links both to the Bund der Gerechten, or League of the Just, which was the network that inflicted communism/Marxism on the world. Antelman wrote:

> The original inner circle of the Bund der Gerechten consisted of born Catholics, Protestants and Jews [Sabbatian-Frankist infiltrators], and those representatives of respective subdivisions formulated schemes for the ultimate destruction of their faiths. The heretical Catholics laid plans which they felt would take a century or more for the ultimate destruction of the church; the apostate Jews for the ultimate destruction of the Jewish religion.

Sabbatian-created communism connects into this anti-religion agenda in that communism does not allow for the free practice of religion. The Sabbatian 'Bund' became the International Communist Party and Communist League and in 1848 'Marxism' was born with the Communist Manifesto of Sabbatian assets Karl Marx and Friedrich Engels. It is absolutely no coincidence that Marxism, just a different name for fascist and other centrally-controlled tyrannies, is being imposed worldwide as a result of the 'Covid' hoax and nor that Marxist/fascist China was the place where the hoax originated. The reason for this will become very clear in the chapter 'Covid: The calculated catastrophe'. The so-called 'Woke' mentality has hijacked

traditional beliefs of the political left and replaced them with far-right make-believe 'social justice' better known as Marxism. Woke will, however, be swallowed by its own perceived 'revolution' which is really the work of billionaires and billionaire corporations feigning being 'Woke'. Marxism is being touted by Wokers as a replacement for 'capitalism' when we don't have 'capitalism'. We have cartelism in which the market is stitched up by the very Cult billionaires and corporations bankrolling Woke. Billionaires love Marxism which keeps the people in servitude while they control from the top. Terminally naïve Wokers think they are 'changing the world' when it's the Cult that is doing the changing and when they have played their vital part and become surplus to requirements they, too, will be targeted. The Illuminati-Jacobins were behind the period known as 'The Terror' in the French Revolution in 1793 and 1794 when Jacobin Maximillian de Robespierre and his Orwellian 'Committee of Public Safety' killed 17,000 'enemies of the Revolution' who had once been 'friends of the Revolution'. Karl Marx (1818-1883), whose Sabbatian creed of Marxism has cost the lives of at least 100 million people, is a hero once again to Wokers who have been systematically kept ignorant of real history by their 'education' programming. As a result they now promote a Sabbatian 'Marxist' abomination destined at some point to consume them. Rabbi Antelman, who spent decades researching the Sabbatian plot, said of the League of the Just and Karl Marx:

> Contrary to popular opinion Karl Marx did not originate the Communist Manifesto. He was paid for his services by the League of the Just, which was known in its country of origin, Germany, as the Bund der Geaechteten.

Antelman said the text attributed to Marx was the work of other people and Marx 'was only repeating what others already said'. Marx was 'a hired hack – lackey of the wealthy Illuminists'. Marx famously said that religion was the 'opium of the people' (part of the Sabbatian plan to demonise religion) and Antelman called his books, *To Eliminate the Opiate*. Marx was born Jewish, but his family converted to Christianity (Sabbatian modus operandi) and he

attacked Jews, not least in his book, *A World Without Jews*. In doing so he supported the Sabbatian plan to destroy traditional Jewishness and Judaism which we are clearly seeing today with the vindictive targeting of orthodox Jews by the Sabbatian government of Israel over 'Covid' laws. I don't follow any religion and it has done much damage to the world over centuries and acted as a perceptual straightjacket. Renegade Minds, however, are always asking *why* something is being done. It doesn't matter if they agree or disagree with what is happening – *why* is it happening is the question. The 'why?' can be answered with regard to religion in that religions create interacting communities of believers when the Cult wants to dismantle all discourse, unity and interaction (see 'Covid' lockdowns) and the ultimate goal is to delete all religions for a one-world religion of Cult Satanism worshipping their 'god' of which more later. We see the same 'why?' with gun control in America. I don't have guns and don't want them, but why is the Cult seeking to disarm the population at the same time that law enforcement agencies are armed to their molars and why has every tyrant in history sought to disarm people before launching the final takeover? They include Hitler, Stalin, Pol Pot and Mao who followed confiscation with violent seizing of power. You know it's a Cult agenda by the people who immediately race to the microphones to exploit dead people in multiple shootings. Ultra-Zionist Cult lackey Senator Chuck Schumer was straight on the case after ten people were killed in Boulder, Colorado in March, 2121. Simple rule … if Schumer wants it the Cult wants it and the same with his ultra-Zionist mate the wild-eyed Senator Adam Schiff. At the same time they were calling for the disarmament of Americans, many of whom live a long way from a police response, Schumer, Schiff and the rest of these pampered clowns were sitting on Capitol Hill behind a razor-wired security fence protected by thousands of armed troops in addition to their own armed bodyguards. Mom and pop in an isolated home? They're just potential mass shooters.

Zion Mainframe

Sabbatian-Frankists and most importantly the Rothschilds were behind the creation of 'Zionism', a political movement that demanded a Jewish homeland in Israel as promised by Sabbatai Zevi. The very symbol of Israel comes from the German meaning of the name Rothschild. Dynasty founder Mayer Amschel Rothschild changed the family name from Bauer to Rothschild, or 'Red-Shield' in German, in deference to the six-pointed 'Star of David' hexagram displayed on the family's home in Frankfurt. The symbol later appeared on the flag of Israel after the Rothschilds were centrally involved in its creation. Hexagrams are not a uniquely Jewish symbol and are widely used in occult ('hidden') networks often as a symbol for Saturn (see my other books for why). Neither are Zionism and Jewishness interchangeable. Zionism is a political movement and philosophy and not a 'race' or a people. Many Jews oppose Zionism and many non-Jews, including US President Joe Biden, call themselves Zionists as does Israel-centric Donald Trump. America's support for the Israel government is pretty much a gimme with ultra-Zionist billionaires and corporations providing fantastic and dominant funding for both political parties. Former Congresswoman Cynthia McKinney has told how she was approached immediately she ran for office to 'sign the pledge' to Israel and confirm that she would always vote in that country's best interests. All American politicians are approached in this way. Anyone who refuses will get no support or funding from the enormous and all-powerful Zionist lobby that includes organisations like mega-lobby group AIPAC, the American Israel Public Affairs Committee. Trump's biggest funder was ultra-Zionist casino and media billionaire Sheldon Adelson while major funders of the Democratic Party include ultra-Zionist George Soros and ultra-Zionist financial and media mogul, Haim Saban. Some may reel back at the suggestion that Soros is an Israel-firster (Sabbatian-controlled Israel-firster), but Renegade Minds watch the actions not the words and everywhere Soros donates his billions the Sabbatian agenda benefits. In the spirit of Sabbatian inversion Soros pledged $1 billion for a new university network to promote 'liberal values and tackle intolerance'. He made the announcement during his annual speech

at the Cult-owned World Economic Forum in Davos, Switzerland, in January, 2020, after his 'harsh criticism' of 'authoritarian rulers' around the world. You can only laugh at such brazen mendacity. How *he* doesn't laugh is the mystery. Translated from the Orwellian 'liberal values and tackle intolerance' means teaching non-white people to hate white people and for white people to loathe themselves for being born white. The reason for that will become clear.

The 'Anti-Semitism' fraud

Zionists support the Jewish homeland in the land of Palestine which has been the Sabbatian-Rothschild goal for so long, but not for the benefit of Jews. Sabbatians and their global Anti-Semitism Industry have skewed public and political opinion to equate opposing the violent extremes of Zionism to be a blanket attack and condemnation of all Jewish people. Sabbatians and their global Anti-Semitism Industry have skewed public and political opinion to equate opposing the violent extremes of Zionism to be a blanket attack and condemnation of all Jewish people. This is nothing more than a Sabbatian protection racket to stop legitimate investigation and exposure of their agendas and activities. The official definition of 'anti-Semitism' has more recently been expanded to include criticism of Zionism – a *political movement* – and this was done to further stop exposure of Sabbatian infiltrators who created Zionism as we know it today in the 19th century. Renegade Minds will talk about these subjects when they know the shit that will come their way. People must decide if they want to know the truth or just cower in the corner in fear of what others will say. Sabbatians have been trying to label me as 'anti-Semitic' since the 1990s as I have uncovered more and more about their background and agendas. Useless, gutless, fraudulent 'journalists' then just repeat the smears without question and on the day I was writing this section a pair of unquestioning repeaters called Ben Quinn and Archie Bland (how appropriate) outright called me an 'anti-Semite' in the establishment propaganda sheet, the London *Guardian*, with no supporting evidence. The

Sabbatian Anti-Semitism Industry said so and who are they to question that? They wouldn't dare. Ironically 'Semitic' refers to a group of languages in the Middle East that are almost entirely Arabic. 'Anti-Semitism' becomes 'anti-Arab' which if the consequences of this misunderstanding were not so grave would be hilarious. Don't bother telling Quinn and Bland. I don't want to confuse them, bless 'em. One reason I am dubbed 'anti-Semitic' is that I wrote in the 1990s that Jewish operatives (Sabbatians) were heavily involved in the Russian Revolution when Sabbatians overthrew the Romanov dynasty. This apparently made me 'anti-Semitic'. Oh, really? Here is a section from *The Trigger*:

British journalist Robert Wilton confirmed these themes in his 1920 book *The Last Days of the Romanovs* when he studied official documents from the Russian government to identify the members of the Bolshevik ruling elite between 1917 and 1919. The Central Committee included 41 Jews among 62 members; the Council of the People's Commissars had 17 Jews out of 22 members; and 458 of the 556 most important Bolshevik positions between 1918 and 1919 were occupied by Jewish people. Only 17 were Russian. Then there were the 23 Jews among the 36 members of the vicious Cheka Soviet secret police established in 1917 who would soon appear all across the country.

Professor Robert Service of Oxford University, an expert on 20th century Russian history, found evidence that ['Jewish'] Leon Trotsky had sought to make sure that Jews were enrolled in the Red Army and were disproportionately represented in the Soviet civil bureaucracy that included the Cheka which performed mass arrests, imprisonment and executions of 'enemies of the people'. A US State Department Decimal File (861.00/5339) dated November 13th, 1918, names [Rothschild banking agent in America] Jacob Schiff and a list of ultra-Zionists as funders of the Russian Revolution leading to claims of a 'Jewish plot', but the key point missed by all is they were not 'Jews' – they were Sabbatian-Frankists.

Britain's Winston Churchill made the same error by mistake or otherwise. He wrote in a 1920 edition of the *Illustrated Sunday Herald* that those behind the Russian revolution were part of a 'worldwide conspiracy for the overthrow of civilisation and for the reconstitution of society on the basis of arrested development, of envious malevolence, and impossible equality' (see 'Woke' today because that has been created by the same network). Churchill said there was no need to exaggerate the part played in the creation of Bolshevism and in the actual bringing about of the Russian

Revolution 'by these international and for the most part atheistical Jews' ['atheistical Jews' = Sabbatians]. Churchill said it is certainly a very great one and probably outweighs all others: 'With the notable exception of Lenin, the majority of the leading figures are Jews.' He went on to describe, knowingly or not, the Sabbatian modus operandi of placing puppet leaders nominally in power while they control from the background:

> Moreover, the principal inspiration and driving power comes from the Jewish leaders. Thus Tchitcherin, a pure Russian, is eclipsed by his nominal subordinate, Litvinoff, and the influence of Russians like Bukharin or Lunacharski cannot be compared with the power of Trotsky, or of Zinovieff, the Dictator of the Red Citadel (Petrograd), or of Krassin or Radek – all Jews. In the Soviet institutions the predominance of Jews is even more astonishing. And the prominent, if not indeed the principal, part in the system of terrorism applied by the Extraordinary Commissions for Combatting Counter-Revolution has been taken by Jews, and in some notable cases by Jewesses.

What I said about seriously disproportionate involvement in the Russian Revolution by Jewish 'revolutionaries' (Sabbatians) is provable fact, but truth is no defence against the Sabbatian Anti-Semitism Industry, its repeater parrots like Quinn and Bland, and the now breathtaking network of so-called 'Woke' 'anti-hate' groups with interlocking leaderships and funding which have the role of discrediting and silencing anyone who gets too close to exposing the Sabbatians. We have seen 'truth is no defence' confirmed in legal judgements with the Saskatchewan Human Rights Commission in Canada decreeing this: 'Truthful statements can be presented in a manner that would meet the definition of hate speech, and not all truthful statements must be free from restriction.' Most 'anti-hate' activists, who are themselves consumed by hatred, are too stupid and ignorant of the world to know how they are being used. They are far too far up their own virtue-signalling arses and it's far too dark for them to see anything.

The 'revolution' game

The background and methods of the 'Russian' Revolution are straight from the Sabbatian playbook seen in the French Revolution

and endless others around the world that appear to start as a revolution of the people against tyrannical rule and end up with a regime change to more tyrannical rule overtly or covertly. Wars, terror attacks and regime overthrows follow the Sabbatian cult through history with its agents creating them as Problem-Reaction-Solutions to remove opposition on the road to world domination. Sabbatian dots connect the Rothschilds with the Illuminati, Jacobins of the French Revolution, the 'Bund' or League of the Just, the International Communist Party, Communist League and the Communist Manifesto of Karl Marx and Friedrich Engels that would lead to the Rothschild-funded Russian Revolution. The sequence comes under the heading of 'creative destruction' when you advance to your global goal by continually destroying the status quo to install a new status quo which you then also destroy. The two world wars come to mind. With each new status quo you move closer to your planned outcome. Wars and mass murder are to Sabbatians a collective blood sacrifice ritual. They are obsessed with death for many reasons and one is that death is an inversion of life. Satanists and Sabbatians are obsessed with death and often target churches and churchyards for their rituals. Inversion-obsessed Sabbatians explain the use of inverted symbolism including the *inverted* pentagram and *inverted* cross. The inversion of the cross has been related to targeting Christianity, but the cross was a religious symbol long before Christianity and its inversion is a statement about the Sabbatian mentality and goals more than any single religion.

Sabbatians operating in Germany were behind the rise of the occult-obsessed Nazis and the subsequent Jewish exodus from Germany and Europe to Palestine and the United States after World War Two. The Rothschild dynasty was at the forefront of this both as political manipulators and by funding the operation. Why would Sabbatians help to orchestrate the horrors inflicted on Jews by the Nazis and by Stalin after they organised the Russian Revolution? Sabbatians hate Jews and their religion, that's why. They pose as Jews and secure positions of control within Jewish society and play the 'anti-Semitism' card to protect themselves from exposure

through a global network of organisations answering to the Sabbatian-created-and-controlled globe-spanning intelligence network that involves a stunning web of military-intelligence operatives and operations for a tiny country of just nine million. Among them are Jewish assets who are not Sabbatians but have been convinced by them that what they are doing is for the good of Israel and the Jewish community to protect them from what they have been programmed since childhood to believe is a Jew-hating hostile world. The Jewish community is just a highly convenient cover to hide the true nature of Sabbatians. Anyone getting close to exposing their game is accused by Sabbatian place-people and gofers of 'anti-Semitism' and claiming that all Jews are part of a plot to take over the world. I am not saying that. I am saying that Sabbatians – the *real* Jew-haters – have infiltrated the Jewish community to use them both as a cover and an 'anti-Semitic' defence against exposure. Thus we have the Anti-Semitism Industry targeted researchers in this way and most Jewish people think this is justified and genuine. They don't know that their 'Jewish' leaders and institutions of state, intelligence and military are not controlled by Jews at all, but cultists and stooges of Sabbatian-Frankism. I once added my name to a pro-Jewish freedom petition online and the next time I looked my name was gone and text had been added to the petition blurb to attack me as an 'anti-Semite' such is the scale of perceptual programming.

Moving on America

I tell the story in *The Trigger* and a chapter called 'Atlantic Crossing' how particularly after Israel was established the Sabbatians moved in on the United States and eventually grasped control of government administration, the political system via both Democrats and Republicans, the intelligence community like the CIA and National Security Agency (NSA), the Pentagon and mass media. Through this seriously compartmentalised network Sabbatians and their operatives in Mossad, Israeli Defense Forces (IDF) and US agencies pulled off 9/11 and blamed it on 19 'Al-Qaeda hijackers' dominated by men from, or connected to, Sabbatian-ruled Saudi

Arabia. The '19' were not even on the planes let alone flew those big passenger jets into buildings while being largely incompetent at piloting one-engine light aircraft. 'Hijacker' Hani Hanjour who is said to have flown American Airlines Flight 77 into the Pentagon with a turn and manoeuvre most professional pilots said they would have struggled to do was banned from renting a small plane by instructors at the Freeway Airport in Bowie, Maryland, just *six weeks* earlier on the grounds that he was an incompetent pilot. The Jewish population of the world is just 0.2 percent with even that almost entirely concentrated in Israel (75 percent Jewish) and the United States (around two percent). This two percent and globally 0.2 percent refers to *Jewish* people and not Sabbatian interlopers who are a fraction of that fraction. What a sobering thought when you think of the fantastic influence on world affairs of tiny Israel and that the Project for the New America Century (PNAC) which laid out the blueprint in September, 2000, for America's war on terror and regime change wars in Iraq, Libya and Syria was founded and dominated by Sabbatians known as 'Neocons'. The document conceded that this plan would not be supported politically or publicly without a major attack on American soil and a Problem-Reaction-Solution excuse to send troops to war across the Middle East. Sabbatian Neocons said:

> ... [The] process of transformation ... [war and regime change] ... is likely to be a long one, absent some catastrophic and catalysing event – like a new Pearl Harbor.

Four months later many of those who produced that document came to power with their inane puppet George Bush from the long-time Sabbatian Bush family. They included Sabbatian Dick Cheney who was officially vice-president, but really de-facto president for the entirety of the 'Bush' government. Nine months after the 'Bush' inauguration came what Bush called at the time 'the Pearl Harbor of the 21st century' and with typical Sabbatian timing and symbolism 2001 was the 60th anniversary of the attack in 1941 by the Japanese Air Force on Pearl Harbor, Hawaii, which allowed President Franklin Delano Roosevelt to take the United States into a Sabbatian-

instigated Second World War that he said in his election campaign that he never would. The evidence is overwhelming that Roosevelt and his military and intelligence networks knew the attack was coming and did nothing to stop it, but they did make sure that America's most essential naval ships were not in Hawaii at the time. Three thousand Americans died in the Pearl Harbor attacks as they did on September 11th. By the 9/11 year of 2001 Sabbatians had widely infiltrated the US government, military and intelligence operations and used their compartmentalised assets to pull off the 'Al-Qaeda' attacks. If you read *The Trigger* it will blow your mind to see the utterly staggering concentration of 'Jewish' operatives (Sabbatian infiltrators) in essential positions of political, security, legal, law enforcement, financial and business power before, during, and after the attacks to make them happen, carry them out, and then cover their tracks – and I do mean *staggering* when you think of that 0.2 percent of the world population and two percent of Americans which are Jewish while Sabbatian infiltrators are a fraction of that. A central foundation of the 9/11 conspiracy was the hijacking of government, military, Air Force and intelligence computer systems in real time through 'back-door' access made possible by Israeli (Sabbatian) 'cyber security' software. Sabbatian-controlled Israel is on the way to rivalling Silicon Valley for domination of cyberspace and is becoming the dominant force in cyber-security which gives them access to entire computer systems and their passcodes across the world. Then add to this that Zionists head (officially) Silicon Valley giants like Google (Larry Page and Sergey Brin), Google-owned YouTube (Susan Wojcicki), Facebook (Mark Zuckerberg and Sheryl Sandberg), and Apple (Chairman Arthur D. Levinson), and that ultra-Zionist hedge fund billionaire Paul Singer has a $1 billion stake in Twitter which is only nominally headed by 'CEO' pothead Jack Dorsey. As cable news host Tucker Carlson said of Dorsey: 'There used to be debate in the medical community whether dropping a ton of acid had permanent effects and I think that debate has now ended.' Carlson made the comment after Dorsey told a hearing on Capitol Hill (if you cut through his bullshit) that he

believed in free speech so long as he got to decide what you can hear and see. These 'big names' of Silicon Valley are only front men and women for the Global Cult, not least the Sabbatians, who are the true controllers of these corporations. Does anyone still wonder why these same people and companies have been ferociously censoring and banning people (like me) for exposing any aspect of the Cult agenda and especially the truth about the 'Covid' hoax which Sabbatians have orchestrated?

The Jeffrey Epstein paedophile ring was a Sabbatian operation. He was officially 'Jewish' but he was a Sabbatian and women abused by the ring have told me about the high number of 'Jewish' people involved. The Epstein horror has Sabbatian written all over it and matches perfectly their modus operandi and obsession with sex and ritual. Epstein was running a Sabbatian blackmail ring in which famous people with political and other influence were provided with young girls for sex while everything was being filmed and recorded on hidden cameras and microphones at his New York house, Caribbean island and other properties. Epstein survivors have described this surveillance system to me and some have gone public. Once the famous politician or other figure knew he or she was on video they tended to do whatever they were told. Here we go again …when you've got them by the balls their hearts and minds will follow. Sabbatians use this blackmail technique on a wide scale across the world to entrap politicians and others they need to act as demanded. Epstein's private plane, the infamous 'Lolita Express', had many well-known passengers including Bill Clinton while Bill Gates has flown on an Epstein plane and met with him four years after Epstein had been jailed for paedophilia. They subsequently met many times at Epstein's home in New York according to a witness who was there. Epstein's infamous side-kick was Ghislaine Maxwell, daughter of Mossad agent and ultra-Zionist mega-crooked British businessman, Bob Maxwell, who at one time owned the *Daily Mirror* newspaper. Maxwell was murdered at sea on his boat in 1991 by Sabbatian-controlled Mossad when he became a liability with his

business empire collapsing as a former Mossad operative has confirmed (see *The Trigger*).

Money, money, money, funny money …

Before I come to the Sabbatian connection with the last three US presidents I will lay out the crucial importance to Sabbatians of controlling banking and finance. Sabbatian Mayer Amschel Rothschild set out to dominate this arena in his family's quest for total global control. What is freedom? It is, in effect, choice. The more choices you have the freer you are and the fewer your choices the more you are enslaved. In the global structure created over centuries by Sabbatians the biggest decider and restrictor of choice is … money. Across the world if you ask people what they would like to do with their lives and why they are not doing that they will reply 'I don't have the money'. This is the idea. A global elite of multi-billionaires are described as 'greedy' and that is true on one level; but control of money – who has it and who doesn't – is not primarily about greed. It's about control. Sabbatians have seized ever more control of finance and sucked the wealth of the world out of the hands of the population. We talk now, after all, about the 'One-percent' and even then the wealthiest are a lot fewer even than that. This has been made possible by a money scam so outrageous and so vast it could rightly be called the scam of scams founded on creating 'money' out of nothing and 'loaning' that with interest to the population. Money out of nothing is called 'credit'. Sabbatians have asserted control over governments and banking ever more completely through the centuries and secured financial laws that allow banks to lend hugely more than they have on deposit in a confidence trick known as fractional reserve lending. Imagine if you could lend money that doesn't exist and charge the recipient interest for doing so. You would end up in jail. Bankers by contrast end up in mansions, private jets, Malibu and Monaco.

Banks are only required to keep a fraction of their deposits and wealth in their vaults and they are allowed to lend 'money' they don't have called 'credit. Go into a bank for a loan and if you succeed

the banker will not move any real wealth into your account. They will type into your account the amount of the agreed 'loan' – say £100,000. This is not wealth that really exists; it is non-existent, fresh-air, created-out-of-nothing 'credit' which has never, does not, and will never exist except in theory. Credit is backed by nothing except wind and only has buying power because people think that it has buying power and accept it in return for property, goods and services. I have described this situation as like those cartoon characters you see chasing each other and when they run over the edge of a cliff they keep running forward on fresh air until one of them looks down, realises what's happened, and they all crash into the ravine. The whole foundation of the Sabbatian financial system is to stop people looking down except for periodic moments when they want to crash the system (as in 2008 and 2020 ongoing) and reap the rewards from all the property, businesses and wealth their borrowers had signed over as 'collateral' in return for a 'loan' of fresh air. Most people think that money is somehow created by governments when it comes into existence from the start as a debt through banks 'lending' illusory money called credit. Yes, the very currency of exchange is a *debt* from day one issued as an interest-bearing loan. Why don't governments create money interest-free and lend it to their people interest-free? Governments are controlled by Sabbatians and the financial system is controlled by Sabbatians for whom interest-free money would be a nightmare come true. Sabbatians underpin their financial domination through their global network of central banks, including the privately-owned US Federal Reserve and Britain's Bank of England, and this is orchestrated by a privately-owned central bank coordination body called the Bank for International Settlements in Basle, Switzerland, created by the usual suspects including the Rockefellers and Rothschilds. Central bank chiefs don't answer to governments or the people. They answer to the Bank for International Settlements or, in other words, the Global Cult which is dominated today by Sabbatians.

Built-in disaster

There are so many constituent scams within the overall banking scam. When you take out a loan of thin-air credit only the amount of that loan is theoretically brought into circulation to add to the amount in circulation; but you are paying back the principle plus interest. The additional interest is not created and this means that with every 'loan' there is a shortfall in the money in circulation between what is borrowed and what has to be paid back. There is never even close to enough money in circulation to repay all outstanding public and private debt including interest. Coldly weaved in the very fabric of the system is the certainty that some will lose their homes, businesses and possessions to the banking 'lender'. This is less obvious in times of 'boom' when the amount of money in circulation (and the debt) is expanding through more people wanting and getting loans. When a downturn comes and the money supply contracts it becomes painfully obvious that there is not enough money to service all debt and interest. This is less obvious in times of 'boom' when the amount of money in circulation (and the debt) is expanding through more people wanting and getting loans. When a downturn comes and the money supply contracts and it becomes painfully obvious – as in 2008 and currently – that there is not enough money to service all debt and interest. Sabbatian banksters have been leading the human population through a calculated series of booms (more debt incurred) and busts (when the debt can't be repaid and the banks get the debtor's tangible wealth in exchange for non-existent 'credit'). With each 'bust' Sabbatian bankers have absorbed more of the world's tangible wealth and we end up with the One-percent. Governments are in bankruptcy levels of debt to the same system and are therefore owned by a system they do not control. The Federal Reserve, 'America's central bank', is privately-owned and American presidents only nominally appoint its chairman or woman to maintain the illusion that it's an arm of government. It's not. The 'Fed' is a cartel of private banks which handed billions to its associates and friends after the crash of 2008 and has been Sabbatian-controlled since it was manipulated into being in 1913 through the covert trickery of Rothschild banking agents Jacob Schiff and Paul

Warburg, and the Sabbatian Rockefeller family. Somehow from a Jewish population of two-percent and globally 0.2 percent (Sabbatian interlopers remember are far smaller) ultra-Zionists headed the Federal Reserve for 31 years between 1987 and 2018 in the form of Alan Greenspan, Bernard Bernanke and Janet Yellen (now Biden's Treasury Secretary) with Yellen's deputy chairman a Israeli-American duel citizen and ultra-Zionist Stanley Fischer, a former governor of the Bank of Israel. Ultra-Zionist Fed chiefs spanned the presidencies of Ronald Reagan ('Republican'), Father George Bush ('Republican'), Bill Clinton ('Democrat'), Boy George Bush ('Republican') and Barack Obama ('Democrat'). We should really add the pre-Greenspan chairman, Paul Adolph Volcker, 'appointed' by Jimmy Carter ('Democrat') who ran the Fed between 1979 and 1987 during the Carter and Reagan administrations before Greenspan took over. Volcker was a long-time associate and business partner of the Rothschilds. No matter what the 'party' officially in power the United States economy was directed by the same force. Here are members of the Obama, Trump and Biden administrations and see if you can make out a common theme.

Barack Obama ('Democrat')

Ultra-Zionists Robert Rubin, Larry Summers, and Timothy Geithner ran the US Treasury in the Clinton administration and two of them reappeared with Obama. Ultra-Zionist Fed chairman Alan Greenspan had manipulated the crash of 2008 through deregulation and jumped ship just before the disaster to make way for ultra-Zionist Bernard Bernanke to hand out trillions to Sabbatian 'too big to fail' banks and businesses, including the ubiquitous ultra-Zionist Goldman Sachs which has an ongoing staff revolving door operation between itself and major financial positions in government worldwide. Obama inherited the fallout of the crash when he took office in January, 2009, and fortunately he had the support of his ultra-Zionist White House Chief of Staff Rahm Emmanuel, son of a terrorist who helped to bomb Israel into being in 1948, and his ultra-Zionist senior adviser David Axelrod, chief strategist in Obama's two

successful presidential campaigns. Emmanuel, later mayor of Chicago and former senior fundraiser and strategist for Bill Clinton, is an example of the Sabbatian policy after Israel was established of migrating insider families to America so their children would be born American citizens. 'Obama' chose this financial team throughout his administration to respond to the Sabbatian-instigated crisis:

Timothy Geithner (ultra-Zionist) Treasury Secretary; Jacob J. Lew, Treasury Secretary; Larry Summers (ultra-Zionist), director of the White House National Economic Council; Paul Adolph Volcker (Rothschild business partner), chairman of the Economic Recovery Advisory Board; Peter Orszag (ultra-Zionist), director of the Office of Management and Budget overseeing all government spending; Penny Pritzker (ultra-Zionist), Commerce Secretary; Jared Bernstein (ultra-Zionist), chief economist and economic policy adviser to Vice President Joe Biden; Mary Schapiro (ultra-Zionist), chair of the Securities and Exchange Commission (SEC); Gary Gensler (ultra-Zionist), chairman of the Commodity Futures Trading Commission (CFTC); Sheila Bair (ultra-Zionist), chair of the Federal Deposit Insurance Corporation (FDIC); Karen Mills (ultra-Zionist), head of the Small Business Administration (SBA); Kenneth Feinberg (ultra-Zionist), Special Master for Executive [bail-out] Compensation. Feinberg would be appointed to oversee compensation (with strings) to 9/11 victims and families in a campaign to stop them having their day in court to question the official story. At the same time ultra-Zionist Bernard Bernanke was chairman of the Federal Reserve and these are only some of the ultra-Zionists with allegiance to Sabbatian-controlled Israel in the Obama government. Obama's biggest corporate donor was ultra-Zionist Goldman Sachs which had employed many in his administration.

Donald Trump ('Republican')

Trump claimed to be an outsider (he wasn't) who had come to 'drain the swamp'. He embarked on this goal by immediately appointing ultra-Zionist Steve Mnuchin, a Goldman Sachs employee for 17

years, as his Treasury Secretary. Others included Gary Cohn (ultra-Zionist), chief operating officer of Goldman Sachs, his first Director of the National Economic Council and chief economic adviser, who was later replaced by Larry Kudlow (ultra-Zionist). Trump's senior adviser throughout his four years in the White House was his sinister son-in-law Jared Kushner, a life-long friend of Israel Prime Minister Benjamin Netanyahu. Kushner is the son of a convicted crook who was pardoned by Trump in his last days in office. Other ultra-Zionists in the Trump administration included: Stephen Miller, Senior Policy Adviser; Avrahm Berkowitz, Deputy Adviser to Trump and his Senior Adviser Jared Kushner; Ivanka Trump, Adviser to the President, who converted to Judaism when she married Jared Kushner; David Friedman, Trump lawyer and Ambassador to Israel; Jason Greenblatt, Trump Organization executive vice president and chief legal officer, who was made Special Representative for International Negotiations and the Israeli-Palestinian Conflict; Rod Rosenstein, Deputy Attorney General; Elliot Abrams, Special Representative for Venezuela, then Iran; John Eisenberg, National Security Council Legal Adviser and Deputy Council to the President for National Security Affairs; Anne Neuberger, Deputy National Manager, National Security Agency; Ezra Cohen-Watnick, Acting Under Secretary of Defense for Intelligence; Elan Carr, Special Envoy to monitor and combat anti-Semitism; Len Khodorkovsky, Deputy Special Envoy to monitor and combat anti-Semitism; Reed Cordish, Assistant to the President, Intragovernmental and Technology Initiatives. Trump Vice President Mike Pence and Secretary of State Mike Pompeo, both Christian Zionists, were also vehement supporters of Israel and its goals and ambitions.

Donald 'free-speech believer' Trump pardoned a number of financial and violent criminals while ignoring calls to pardon Julian Assange and Edward Snowden whose crimes are revealing highly relevant information about government manipulation and corruption and the widespread illegal surveillance of the American people by US 'security' agencies. It's so good to know that Trump is on the side of freedom and justice and not mega-criminals with

allegiance to Sabbatian-controlled Israel. These included a pardon for Israeli spy Jonathan Pollard who was jailed for life in 1987 under the Espionage Act. Aviem Sella, the Mossad agent who recruited Pollard, was also pardoned by Trump while Assange sat in jail and Snowden remained in exile in Russia. Sella had 'fled' (was helped to escape) to Israel in 1987 and was never extradited despite being charged under the Espionage Act. A Trump White House statement said that Sella's clemency had been 'supported by Benjamin Netanyahu, Ron Dermer, Israel's US Ambassador, David Friedman, US Ambassador to Israel and Miriam Adelson, wife of leading Trump donor Sheldon Adelson who died shortly before. Other friends of Jared Kushner were pardoned along with Sholom Weiss who was believed to be serving the longest-ever white-collar prison sentence of more than 800 years in 2000. The sentence was commuted of Ponzi-schemer Eliyahu Weinstein who defrauded Jews and others out of $200 million. I did mention that Assange and Snowden were ignored, right? Trump gave Sabbatians almost everything they asked for in military and political support, moving the US Embassy from Tel Aviv to Jerusalem with its critical symbolic and literal implications for Palestinian statehood, and the 'deal of the Century' designed by Jared Kushner and David Friedman which gave the Sabbatian Israeli government the green light to substantially expand its already widespread program of building illegal Jewish-only settlements in the occupied land of the West Bank. This made a two-state 'solution' impossible by seizing all the land of a potential Palestinian homeland and that had been the plan since 1948 and then 1967 when the Arab-controlled Gaza Strip, West Bank, Sinai Peninsula and Syrian Golan Heights were occupied by Israel. All the talks about talks and road maps and delays have been buying time until the West Bank was physically occupied by Israeli real estate. Trump would have to be a monumentally ill-informed idiot not to see that this was the plan he was helping to complete. The Trump administration was in so many ways the Kushner administration which means the Netanyahu administration which means the Sabbatian administration. I understand why many opposing Cult fascism in all its forms gravitated to Trump, but he

was a crucial part of the Sabbatian plan and I will deal with this in the next chapter.

Joe Biden ('Democrat')

A barely cognitive Joe Biden took over the presidency in January, 2021, along with his fellow empty shell, Vice-President Kamala Harris, as the latest Sabbatian gofers to enter the White House. Names on the door may have changed and the 'party' – the force behind them remained the same as Zionists were appointed to a stream of pivotal areas relating to Sabbatian plans and policy. They included: Janet Yellen, Treasury Secretary, former head of the Federal Reserve, and still another ultra-Zionist running the US Treasury after Mnuchin (Trump), Lew and Geithner (Obama), and Summers and Rubin (Clinton); Anthony Blinken, Secretary of State; Wendy Sherman, Deputy Secretary of State (so that's 'Biden's' Sabbatian foreign policy sorted); Jeff Zients, White House coronavirus coordinator; Rochelle Walensky, head of the Centers for Disease Control; Rachel Levine, transgender deputy health secretary (that's 'Covid' hoax policy under control); Merrick Garland, Attorney General; Alejandro Mayorkas, Secretary of Homeland Security; Cass Sunstein, Homeland Security with responsibility for new immigration laws; Avril Haines, Director of National Intelligence; Anne Neuberger, National Security Agency cybersecurity director (note, cybersecurity); David Cohen, CIA Deputy Director; Ronald Klain, Biden's Chief of Staff (see Rahm Emanuel); Eric Lander, a 'leading geneticist', Office of Science and Technology Policy director (see Smart Grid, synthetic biology agenda); Jessica Rosenworcel, acting head of the Federal Communications Commission (FCC) which controls Smart Grid technology policy and electromagnetic communication systems including 5G. How can it be that so many pivotal positions are held by two-percent of the American population and 0.2 percent of the world population administration after administration no matter who is the president and what is the party? It's a coincidence? Of course it's not and this is why Sabbatians have built their colossal global web of interlocking 'anti-

hate' hate groups to condemn anyone who asks these glaring questions as an 'anti-Semite'. The way that Jewish people horrifically abused in Sabbatian-backed Nazi Germany are exploited to this end is stomach-turning and disgusting beyond words.

Political fusion

Sabbatian manipulation has reversed the roles of Republicans and Democrats and the same has happened in Britain with the Conservative and Labour Parties. Republicans and Conservatives were always labelled the 'right' and Democrats and Labour the 'left', but look at the policy positions now and the Democrat-Labour 'left' has moved further to the 'right' than Republicans and Conservatives under the banner of 'Woke', the Cult-created far-right tyranny. Where once the Democrat-Labour 'left' defended free speech and human rights they now seek to delete them and as I said earlier despite the 'Covid' fascism of the Jackboot Johnson Conservative government in the UK the Labour Party of leader Keir Starmer demanded even more extreme measures. The Labour Party has been very publicly absorbed by Sabbatians after a political and media onslaught against the previous leader, the weak and inept Jeremy Corbyn, over made-up allegations of 'anti-Semitism' both by him and his party. The plan was clear with this 'anti-Semite' propaganda and what was required in response was a swift and decisive 'fuck off' from Corbyn and a statement to expose the Anti-Semitism Industry (Sabbatian) attempt to silence Labour criticism of the Israeli government (Sabbatians) and purge the party of all dissent against the extremes of ultra-Zionism (Sabbatians). Instead Corbyn and his party fell to their knees and appeased the abusers which, by definition, is impossible. Appeasing one demand leads only to a new demand to be appeased until takeover is complete. Like I say – 'fuck off' would have been a much more effective policy and I have used it myself with great effect over the years when Sabbatians are on my case which is most of the time. I consider that fact a great compliment, by the way. The outcome of the Labour Party capitulation is that we now have a Sabbatian-controlled

Conservative Party 'opposed' by a Sabbatian-controlled Labour Party in a one-party Sabbatian state that hurtles towards the extremes of tyranny (the Sabbatian cult agenda). In America the situation is the same. Labour's Keir Starmer spends his days on his knees with his tongue out pointing to Tel Aviv, or I guess now Jerusalem, while Boris Johnson has an 'anti-Semitism czar' in the form of former Labour MP John Mann who keeps Starmer company on his prayer mat.

Sabbatian influence can be seen in Jewish members of the Labour Party who have been ejected for criticism of Israel including those from families that suffered in Nazi Germany. Sabbatians despise real Jewish people and target them even more harshly because it is so much more difficult to dub them 'anti-Semitic' although in their desperation they do try.

CHAPTER THREE

The Pushbacker sting

Until you realize how easy it is for your mind to be manipulated, you remain the puppet of someone else's game
Evita Ochel

I will use the presidencies of Trump and Biden to show how the manipulation of the one-party state plays out behind the illusion of political choice across the world. No two presidencies could – on the face of it – be more different and apparently at odds in terms of direction and policy.

A Renegade Mind sees beyond the obvious and focuses on outcomes and consequences and not image, words and waffle. The Cult embarked on a campaign to divide America between those who blindly support its agenda (the mentality known as 'Woke') and those who are pushing back on where the Cult and its Sabbatians want to go. This presents infinite possibilities for dividing and ruling the population by setting them at war with each other and allows a perceptual ring fence of demonisation to encircle the Pushbackers in a modern version of the Little Big Horn in 1876 when American cavalry led by Lieutenant Colonel George Custer were drawn into a trap, surrounded and killed by Native American tribes defending their land of thousands of years from being seized by the government. In this modern version the roles are reversed and it's those defending themselves from the Sabbatian government who are surrounded and the government that's seeking to destroy them. This trap was set years ago and to explain how we must return to 2016

and the emergence of Donald Trump as a candidate to be President of the United States. He set out to overcome the best part of 20 other candidates in the Republican Party before and during the primaries and was not considered by many in those early stages to have a prayer of living in the White House. The Republican Party was said to have great reservations about Trump and yet somehow he won the nomination. When you know how American politics works – politics in general – there is no way that Trump could have become the party's candidate unless the Sabbatian-controlled 'Neocons' that run the Republican Party wanted that to happen. We saw the proof in emails and documents made public by WikiLeaks that the Democratic Party hierarchy, or Democons, systematically undermined the campaign of Bernie Sanders to make sure that Sabbatian gofer Hillary Clinton won the nomination to be their presidential candidate. If the Democons could do that then the Neocons in the Republican Party could have derailed Trump in the same way. But they didn't and at that stage I began to conclude that Trump could well be the one chosen to be president. If that was the case the 'why' was pretty clear to see – the goal of dividing America between Cult agenda-supporting Wokers and Pushbackers who gravitated to Trump because he was telling them what they wanted to hear. His constituency of support had been increasingly ignored and voiceless for decades and profoundly through the eight years of Sabbatian puppet Barack Obama. Now here was someone speaking their language of pulling back from the incessant globalisation of political and economic power, the exporting of American jobs to China and elsewhere by 'American' (Sabbatian) corporations, the deletion of free speech, and the mass immigration policies that had further devastated job opportunities for the urban working class of all races and the once American heartlands of the Midwest.

Beware the forked tongue

Those people collectively sighed with relief that at last a political leader was apparently on their side, but another trait of the Renegade Mind is that you look even harder at people telling you

what you want to hear than those who are telling you otherwise. Obviously as I said earlier people wish what they want to hear to be true and genuine and they are much more likely to believe that than someone saying what they don't want to here and don't want to be true. Sales people are taught to be skilled in eliciting by calculated questioning what their customers want to hear and repeating that back to them as their own opinion to get their targets to like and trust them. Assets of the Cult are also sales people in the sense of selling perception. To read Cult manipulation you have to play the long and expanded game and not fall for the Vaudeville show of party politics. Both American parties are vehicles for the Cult and they exploit them in different ways depending on what the agenda requires at that moment. Trump and the Republicans were used to be the focus of dividing America and isolating Pushbackers to open the way for a Biden presidency to become the most extreme in American history by advancing the full-blown Woke (Cult) agenda with the aim of destroying and silencing Pushbackers now labelled Nazi Trump supporters and white supremacists.

Sabbatians wanted Trump in office for the reasons described by ultra-Zionist Saul Alinsky (1909-1972) who was promoting the Woke philosophy through 'community organising' long before anyone had heard of it. In those days it still went by its traditional name of Marxism. The reason for the manipulated Trump phenomenon was laid out in Alinsky's 1971 book, *Rules for Radicals*, which was his blueprint for overthrowing democratic and other regimes and replacing them with Sabbatian Marxism. Not surprisingly his to-do list was evident in the Sabbatian French and Russian 'Revolutions' and that in China which will become very relevant in the next chapter about the 'Covid' hoax. Among Alinsky's followers have been the deeply corrupt Barack Obama, House Speaker Nancy Pelosi and Hillary Clinton who described him as a 'hero'. All three are Sabbatian stooges with Pelosi personifying the arrogant corrupt idiocy that so widely fronts up for the Cult inner core. Predictably as a Sabbatian advocate of the 'light-bringer' Alinsky features Lucifer on the dedication page of his book as the original radical who gained

his own kingdom ('Earth' as we shall see). One of Alinsky's golden radical rules was to pick an individual and focus all attention, hatred and blame on them and not to target faceless bureaucracies and corporations. *Rules for Radicals* is really a Sabbatian handbook with its contents repeatedly employed all over the world for centuries and why wouldn't Sabbatians bring to power their designer-villain to be used as the individual on which all attention, hatred and blame was bestowed? This is what they did and the only question for me is how much Trump knew that and how much he was manipulated. A bit of both, I suspect. This was Alinsky's Trump technique from a man who died in 1972. The technique has spanned history:

Pick the target, freeze it, personalize it, polarize it. Don't try to attack abstract corporations or bureaucracies. Identify a responsible individual. Ignore attempts to shift or spread the blame.

From the moment Trump came to illusory power everything was about him. It wasn't about Republican policy or opinion, but all about Trump. Everything he did was presented in negative, derogatory and abusive terms by the Sabbatian-dominated media led by Cult operations such as CNN, MSNBC, *The New York Times* and the Jeff Bezos-owned *Washington Post* – 'Pick the target, freeze it, personalize it, polarize it.' Trump was turned into a demon to be vilified by those who hated him and a demi-god loved by those who worshipped him. This, in turn, had his supporters, too, presented as equally demonic in preparation for the punchline later down the line when Biden was about to take office. It was here's a Trump, there's a Trump, everywhere a Trump, Trump. Virtually every news story or happening was filtered through the lens of 'The Donald'. You loved him or hated him and which one you chose was said to define you as Satan's spawn or a paragon of virtue. Even supporting some Trump policies or statements and not others was enough for an assault on your character. No shades of grey were or are allowed. Everything is black and white (literally and figuratively). A Californian I knew had her head utterly scrambled by her hatred for Trump while telling people they should love each other. She was so totally consumed by

Trump Derangement Syndrome as it became to be known that this glaring contradiction would never have occurred to her. By definition anyone who criticised Trump or praised his opponents was a hero and this lady described Joe Biden as 'a kind, honest gentleman' when he's a provable liar, mega-crook and vicious piece of work to boot. Sabbatians had indeed divided America using Trump as the fall-guy and all along the clock was ticking on the consequences for his supporters.

In hock to his masters

Trump gave Sabbatians via Israel almost everything they wanted in his four years. Ask and you shall receive was the dynamic between himself and Benjamin Netanyahu orchestrated by Trump's ultra-Zionist son-in-law Jared Kushner, his ultra-Zionist Ambassador to Israel, David Friedman, and ultra-Zionist 'Israel adviser', Jason Greenblatt. The last two were central to the running and protecting from collapse of his business empire, the Trump Organisation, and colossal business failures made him forever beholding to Sabbatian networks that bailed him out. By the start of the 1990s Trump owed $4 billion to banks that he couldn't pay and almost $1billion of that was down to him personally and not his companies. This mega-disaster was the result of building two new casinos in Atlantic City and buying the enormous Taj Mahal operation which led to crippling debt payments. He had borrowed fantastic sums from 72 banks with major Sabbatian connections and although the scale of debt should have had him living in a tent alongside the highway they never foreclosed. A plan was devised to lift Trump from the mire by BT Securities Corporation and Rothschild Inc. and the case was handled by Wilber Ross who had worked for the Rothschilds for 27 years. Ross would be named US Commerce Secretary after Trump's election. Another crucial figure in saving Trump was ultra-Zionist 'investor' Carl Icahn who bought the Taj Mahal casino. Icahn was made special economic adviser on financial regulation in the Trump administration. He didn't stay long but still managed to find time to make a tidy sum of a reported $31.3 million when he sold his

holdings affected by the price of steel three days before Trump imposed a 235 percent tariff on steel imports. What amazing bits of luck these people have. Trump and Sabbatian operatives have long had a close association and his mentor and legal adviser from the early 1970s until 1986 was the dark and genetically corrupt ultra-Zionist Roy Cohn who was chief counsel to Senator Joseph McCarthy's 'communist' witch-hunt in the 1950s. *Esquire* magazine published an article about Cohn with the headline 'Don't mess with Roy Cohn'. He was described as the most feared lawyer in New York and 'a ruthless master of dirty tricks ... [with] ... more than one Mafia Don on speed dial'. Cohn's influence, contacts, support and protection made Trump a front man for Sabbatians in New York with their connections to one of Cohn's many criminal employers, the 'Russian' Sabbatian Mafia. Israel-centric media mogul Rupert Murdoch was introduced to Trump by Cohn and they started a long friendship. Cohn died in 1986 weeks after being disbarred for unethical conduct by the Appellate Division of the New York State Supreme Court. The wheels of justice do indeed run slow given the length of Cohn's crooked career.

QAnon-sense

We are asked to believe that Donald Trump with his fundamental connections to Sabbatian networks and operatives has been leading the fight to stop the Sabbatian agenda for the fascistic control of America and the world. Sure he has. A man entrapped during his years in the White House by Sabbatian operatives and whose biggest financial donor was casino billionaire Sheldon Adelson who was Sabbatian to his DNA?? Oh, do come on. Trump has been used to divide America and isolate Pushbackers on the Cult agenda under the heading of 'Trump supporters', 'insurrectionists' and 'white supremacists'. The US Intelligence/Mossad Psyop or psychological operation known as QAnon emerged during the Trump years as a central pillar in the Sabbatian campaign to lead Pushbackers into the trap set by those that wished to destroy them. I knew from the start that QAnon was a scam because I had seen the same scenario many

times before over 30 years under different names and I had written about one in particular in the books. 'Not again' was my reaction when QAnon came to the fore. The same script is pulled out every few years and a new name added to the letterhead. The story always takes the same form: 'Insiders' or 'the good guys' in the government-intelligence-military 'Deep State' apparatus were going to instigate mass arrests of the 'bad guys' which would include the Rockefellers, Rothschilds, Barack Obama, Hillary Clinton, George Soros, etc., etc. Dates are given for when the 'good guys' are going to move in, but the dates pass without incident and new dates are given which pass without incident. The central message to Pushbackers in each case is that they don't have to do anything because there is 'a plan' and it is all going to be sorted by the 'good guys' on the inside. 'Trust the plan' was a QAnon mantra when the only plan was to misdirect Pushbackers into putting their trust in a Psyop they believed to be real. Beware, beware, those who tell you what you want to hear and always check it out. Right up to Biden's inauguration QAnon was still claiming that 'the Storm' was coming and Trump would stay on as president when Biden and his cronies were arrested and jailed. It was never going to happen and of course it didn't, but what did happen as a result provided that punchline to the Sabbatian Trump/QAnon Psyop.

On January 6th, 2021, a very big crowd of Trump supporters gathered in the National Mall in Washington DC down from the Capitol Building to protest at what they believed to be widespread corruption and vote fraud that stopped Trump being re-elected for a second term as president in November, 2020. I say as someone that does not support Trump or Biden that the evidence is clear that major vote-fixing went on to favour Biden, a man with cognitive problems so advanced he can often hardly string a sentence together without reading the words written for him on the Teleprompter. Glaring ballot discrepancies included serious questions about electronic voting machines that make vote rigging a comparative cinch and hundreds of thousands of paper votes that suddenly appeared during already advanced vote counts and virtually all of

them for Biden. Early Trump leads in crucial swing states suddenly began to close and disappear. The pandemic hoax was used as the excuse to issue almost limitless numbers of mail-in ballots with no checks to establish that the recipients were still alive or lived at that address. They were sent to streams of people who had not even asked for them. Private organisations were employed to gather these ballots and who knows what they did with them before they turned up at the counts. The American election system has been manipulated over decades to become a sick joke with more holes than a Swiss cheese for the express purpose of dictating the results. Then there was the criminal manipulation of information by Sabbatian tech giants like Facebook, Twitter and Google-owned YouTube which deleted pro-Trump, anti-Biden accounts and posts while everything in support of Biden was left alone. Sabbatians wanted Biden to win because after the dividing of America it was time for full-on Woke and every aspect of the Cult agenda to be unleashed.

Hunter gatherer

Extreme Silicon Valley bias included blocking information by the *New York Post* exposing a Biden scandal that should have ended his bid for president in the final weeks of the campaign. Hunter Biden, his monumentally corrupt son, is reported to have sent a laptop to be repaired at a local store and failed to return for it. Time passed until the laptop became the property of the store for non-payment of the bill. When the owner saw what was on the hard drive he gave a copy to the FBI who did nothing even though it confirmed widespread corruption in which the Joe Biden family were using his political position, especially when he was vice president to Obama, to make multiple millions in countries around the world and most notably Ukraine and China. Hunter Biden's one-time business partner Tony Bobulinski went public when the story broke in the *New York Post* to confirm the corruption he saw and that Joe Biden not only knew what was going on he also profited from the spoils. Millions were handed over by a Chinese company with close

connections – like all major businesses in China – to the Chinese communist party of President Xi Jinping. Joe Biden even boasted at a meeting of the Cult's World Economic Forum that as vice president he had ordered the government of Ukraine to fire a prosecutor. What he didn't mention was that the same man just happened to be investigating an energy company which was part of Hunter Biden's corrupt portfolio. The company was paying him big bucks for no other reason than the influence his father had. Overnight Biden's presidential campaign should have been over given that he had lied publicly about not knowing what his son was doing. Instead almost the entire Sabbatian-owned mainstream media and Sabbatian-owned Silicon Valley suppressed circulation of the story. This alone went a mighty way to rigging the election of 2020. Cult assets like Mark Zuckerberg at Facebook also spent hundreds of millions to be used in support of Biden and vote 'administration'.

The Cult had used Trump as the focus to divide America and was now desperate to bring in moronic, pliable, corrupt Biden to complete the double-whammy. No way were they going to let little things like the will of the people thwart their plan. Silicon Valley widely censored claims that the election was rigged because it *was* rigged. For the same reason anyone claiming it was rigged was denounced as a 'white supremacist' including the pathetically few Republican politicians willing to say so. Right across the media where the claim was mentioned it was described as a 'false claim' even though these excuses for 'journalists' would have done no research into the subject whatsoever. Trump won seven million more votes than any sitting president had ever achieved while somehow a cognitively-challenged soon to be 78-year-old who was hidden away from the public for most of the campaign managed to win more votes than any presidential candidate in history. It makes no sense. You only had to see election rallies for both candidates to witness the enthusiasm for Trump and the apathy for Biden. Tens of thousands would attend Trump events while Biden was speaking in empty car parks with often only television crews attending and framing their shots to hide the fact that no one was there. It was pathetic to see

footage come to light of Biden standing at a podium making speeches only to TV crews and party fixers while reading the words written for him on massive Teleprompter screens. So, yes, those protestors on January 6th had a point about election rigging, but some were about to walk into a trap laid for them in Washington by the Cult Deep State and its QAnon Psyop. This was the Capitol Hill riot ludicrously dubbed an 'insurrection'.

The spider and the fly

Renegade Minds know there are not two 'sides' in politics, only one side, the Cult, working through all 'sides'. It's a stage show, a puppet show, to direct the perceptions of the population into focusing on diversions like parties and candidates while missing the puppeteers with their hands holding all the strings. The Capitol Hill 'insurrection' brings us back to the Little Big Horn. Having created two distinct opposing groupings – Woke and Pushbackers – the trap was about to be sprung. Pushbackers were to be encircled and isolated by associating them all in the public mind with Trump and then labelling Trump as some sort of Confederate leader. I knew immediately that the Capitol riot was a set-up because of two things. One was how easy the rioters got into the building with virtually no credible resistance and secondly I could see – as with the 'Covid' hoax in the West at the start of 2020 – how the Cult could exploit the situation to move its agenda forward with great speed. My experience of Cult techniques and activities over more than 30 years has showed me that while they do exploit situations they haven't themselves created this never happens with events of fundamental agenda significance. Every time major events giving cultists the excuse to rapidly advance their plan you find they are manipulated into being for the specific reason of providing that excuse – Problem-Reaction-Solution. Only a tiny minority of the huge crowd of Washington protestors sought to gain entry to the Capitol by smashing windows and breaching doors. That didn't matter. The whole crowd and all Pushbackers, even if they did not support Trump, were going to be lumped together as dangerous

insurrectionists and conspiracy theorists. The latter term came into widespread use through a CIA memo in the 1960s aimed at discrediting those questioning the nonsensical official story of the Kennedy assassination and it subsequently became widely employed by the media. It's still being used by inept 'journalists' with no idea of its origin to discredit anyone questioning anything that authority claims to be true. When you are perpetrating a conspiracy you need to discredit the very word itself even though the dictionary definition of conspiracy is merely 'the activity of secretly planning with other people to do something bad or illegal' and 'a general agreement to keep silent about a subject for the purpose of keeping it secret'. On that basis there are conspiracies almost wherever you look. For obvious reasons the Cult and its lapdog media have to claim there are no conspiracies even though the word appears in state laws as with conspiracy to defraud, to murder, and to corrupt public morals.

Agent provocateurs are widely used by the Cult Deep State to manipulate genuine people into acting in ways that suit the desired outcome. By genuine in this case I mean protestors genuinely supporting Trump and claims that the election was stolen. In among them, however, were agents of the state wearing the garb of Trump supporters and QAnon to pump-prime the Capital riot which some genuine Trump supporters naively fell for. I described the situation as 'Come into my parlour said the spider to the fly'. Leaflets appeared through the Woke paramilitary arm Antifa, the anti-fascist fascists, calling on supporters to turn up in Washington looking like Trump supporters even though they hated him. Some of those arrested for breaching the Capitol Building were sourced to Antifa and its stable mate Black Lives Matter. Both organisations are funded by Cult billionaires and corporations. One man charged for the riot was according to his lawyer a former FBI agent who had held top secret security clearance for 40 years. Attorney Thomas Plofchan said of his client, 66-year-old Thomas Edward Caldwell:

He has held a Top Secret Security Clearance since 1979 and has undergone multiple Special Background Investigations in support of his clearances. After retiring from the Navy, he

worked as a section chief for the Federal Bureau of Investigation from 2009-2010 as a GS-12 [mid-level employee].

He also formed and operated a consulting firm performing work, often classified, for U.S government customers including the US. Drug Enforcement Agency, Department of Housing and Urban Development, the US Coast Guard, and the US Army Personnel Command.

A judge later released Caldwell pending trial in the absence of evidence about a conspiracy or that he tried to force his way into the building. *The New York Post* reported a 'law enforcement source' as saying that 'at least two known Antifa members were spotted' on camera among Trump supporters during the riot while one of the rioters arrested was John Earle Sullivan, a seriously extreme Black Lives Matter Trump-hater from Utah who was previously arrested and charged in July, 2020, over a BLM-Antifa riot in which drivers were threatened and one was shot. Sullivan is the founder of Utah-based Insurgence USA which is an affiliate of the Cult-created-and-funded Black Lives Matter movement. Footage appeared and was then deleted by Twitter of Trump supporters calling out Antifa infiltrators and a group was filmed changing into pro-Trump clothing before the riot. Security at the building was *pathetic* – as planned. Colonel Leroy Fletcher Prouty, a man with long experience in covert operations working with the US security apparatus, once described the tell-tale sign to identify who is involved in an assassination. He said:

No one has to direct an assassination – it happens. The active role is played secretly by permitting it to happen. This is the greatest single clue. Who has the power to call off or reduce the usual security precautions?

This principle applies to many other situations and certainly to the Capitol riot of January 6th, 2021.

The sting

With such a big and potentially angry crowd known to be gathering near the Capitol the security apparatus would have had a major police detail to defend the building with National Guard troops on

standby given the strength of feeling among people arriving from all over America encouraged by the QAnon Psyop and statements by Donald Trump. Instead Capitol Police 'security' was flimsy, weak, and easily breached. The same number of officers was deployed as on a regular day and that is a blatant red flag. They were not staffed or equipped for a possible riot that had been an obvious possibility in the circumstances. No protective and effective fencing worth the name was put in place and there were no contingency plans. The whole thing was basically a case of standing aside and waving people in. Once inside police mostly backed off apart from one Capitol police officer who ridiculously shot dead unarmed Air Force veteran protestor Ashli Babbitt without a warning as she climbed through a broken window. The 'investigation' refused to name or charge the officer after what must surely be considered a murder in the circumstances. They just lifted a carpet and swept. The story was endlessly repeated about five people dying in the 'armed insurrection' when there was no report of rioters using weapons. Apart from Babbitt the other four died from a heart attack, strokes and apparently a drug overdose. Capitol police officer Brian Sicknick was reported to have died after being bludgeoned with a fire extinguisher when he was alive after the riot was over and died later of what the Washington Medical Examiner's Office said was a stroke. Sicknick had no external injuries. The lies were delivered like rapid fire. There was a narrative to build with incessant repetition of the lie until the lie became the accepted 'everybody knows that' truth. The 'Big Lie' technique of Nazi Propaganda Minister Joseph Goebbels is constantly used by the Cult which was behind the Nazis and is today behind the 'Covid' and 'climate change' hoaxes. Goebbels said:

If you tell a lie big enough and keep repeating it, people will eventually come to believe it. The lie can be maintained only for such time as the State can shield the people from the political, economic and/or military consequences of the lie. It thus becomes vitally important for the State to use all of its powers to repress dissent, for the truth is the mortal enemy of the lie, and thus by extension, the truth is the greatest enemy of the State.

Most protestors had a free run of the Capitol Building. This allowed pictures to be taken of rioters in iconic parts of the building including the Senate chamber which could be used as propaganda images against all Pushbackers. One Congresswoman described the scene as 'the worst kind of non-security anybody could ever imagine'. Well, the first part was true, but someone obviously did imagine it and made sure it happened. Some photographs most widely circulated featured people wearing QAnon symbols and now the Psyop would be used to dub all QAnon followers with the ubiquitous fit-all label of 'white supremacist' and 'insurrectionists'. When a Muslim extremist called Noah Green drove his car at two police officers at the Capitol Building killing one in April, 2021, there was no such political and media hysteria. They were just disappointed he wasn't white.

The witch-hunt

Government prosecutor Michael Sherwin, an aggressive, dark-eyed, professional Rottweiler led the 'investigation' and to call it over the top would be to understate reality a thousand fold. Hundreds were tracked down and arrested for the crime of having the wrong political views and people were jailed who had done nothing more than walk in the building, committed no violence or damage to property, took a few pictures and left. They were labelled a 'threat to the Republic' while Biden sat in the White House signing executive orders written for him that were dismantling 'the Republic'. Even when judges ruled that a mother and son should not be in jail the government kept them there. Some of those arrested have been badly beaten by prison guards in Washington and lawyers for one man said he suffered a fractured skull and was made blind in one eye. Meanwhile a woman is shot dead for no reason by a Capitol Police officer and we are not allowed to know who he is never mind what has happened to him although that will be *nothing*. The Cult's QAnon/Trump sting to identify and isolate Pushbackers and then target them on the road to crushing and deleting them was a resounding success. You would have thought the Russians had

invaded the building at gunpoint and lined up senators for a firing squad to see the political and media reaction. Congresswoman Alexandria Ocasio-Cortez is a child in a woman's body, a terrible-twos, me, me, me, Woker narcissist of such proportions that words have no meaning. She said she thought she was going to die when 'insurrectionists' banged on her office door. It turned out she wasn't even in the Capitol Building when the riot was happening and the 'banging' was a Capitol Police officer. She referred to herself as a 'survivor' which is an insult to all those true survivors of violent and sexual abuse while she lives her pampered and privileged life talking drivel for a living. Her Woke colleague and fellow mega-narcissist Rashida Tlaib broke down describing the devastating effect on her, too, of *not being* in the building when the rioters were there. Ocasio-Cortez and Tlaib are members of a fully-Woke group of Congresswomen known as 'The Squad' along with Ilhan Omar and Ayanna Pressley. The Squad from what I can see can be identified by its vehement anti-white racism, anti-white men agenda, and, as always in these cases, the absence of brain cells on active duty.

The usual suspects were on the riot case immediately in the form of Democrat ultra-Zionist senators and operatives Chuck Schumer and Adam Schiff demanding that Trump be impeached for 'his part in the insurrection'. The same pair of prats had led the failed impeachment of Trump over the invented 'Russia collusion' nonsense which claimed Russia had helped Trump win the 2016 election. I didn't realise that Tel Aviv had been relocated just outside Moscow. I must find an up-to-date map. The Russia hoax was a Sabbatian operation to keep Trump occupied and impotent and to stop any rapport with Russia which the Cult wants to retain as a perceptual enemy to be pulled out at will. Puppet Biden began attacking Russia when he came to office as the Cult seeks more upheaval, division and war across the world. A two-year stage show 'Russia collusion inquiry' headed by the not-very-bright former 9/11 FBI chief Robert Mueller, with support from 19 lawyers, 40 FBI agents plus intelligence analysts, forensic accountants and other

staff, devoured tens of millions of dollars and found no evidence of Russia collusion which a ten-year-old could have told them on day one. Now the same moronic Schumer and Schiff wanted a second impeachment of Trump over the Capitol 'insurrection' (riot) which the arrested development of Schumer called another 'Pearl Harbor' while others compared it with 9/11 in which 3,000 died and, in the case of CNN, with the Rwandan genocide in the 1990s in which an estimated 500,000 to 600,000 were murdered, between 250, 000 and 500,000 women were raped, and populations of whole towns were hacked to death with machetes. To make those comparisons purely for Cult political reasons is beyond insulting to those that suffered and lost their lives and confirms yet again the callous inhumanity that we are dealing with. Schumer is a monumental idiot and so is Schiff, but they serve the Cult agenda and do whatever they're told so they get looked after. Talking of idiots – another inane man who spanned the Russia and Capitol impeachment attempts was Senator Eric Swalwell who had the nerve to accuse Trump of collusion with the Russians while sleeping with a Chinese spy called Christine Fang or 'Fang Fang' which is straight out of a Bond film no doubt starring Klaus Schwab as the bloke living on a secret island and controlling laser weapons positioned in space and pointing at world capitals. Fang Fang plays the part of Bond's infiltrator girlfriend which I'm sure she would enjoy rather more than sharing a bed with the brainless Swalwell, lying back and thinking of China. The FBI eventually warned Swalwell about Fang Fang which gave her time to escape back to the Chinese dictatorship. How very thoughtful of them. The second Trump impeachment also failed and hardly surprising when an impeachment is supposed to remove a sitting president and by the time it happened Trump was no longer president. These people are running your country America, well, officially anyway. Terrifying isn't it?

Outcomes tell the story - always

The outcome of all this – and it's the *outcome* on which Renegade Minds focus, not the words – was that a vicious, hysterical and

obviously pre-planned assault was launched on Pushbackers to censor, silence and discredit them and even targeted their right to earn a living. They have since been condemned as 'domestic terrorists' that need to be treated like Al-Qaeda and Islamic State. 'Domestic terrorists' is a label the Cult has been trying to make stick since the period of the Oklahoma bombing in 1995 which was blamed on 'far-right domestic terrorists'. If you read *The Trigger* you will see that the bombing was clearly a Problem-Reaction-Solution carried out by the Deep State during a Bill Clinton administration so corrupt that no dictionary definition of the term would even nearly suffice. Nearly 30, 000 troops were deployed from all over America to the empty streets of Washington for Biden's inauguration. Ten thousand of them stayed on with the pretext of protecting the capital from insurrectionists when it was more psychological programming to normalise the use of the military in domestic law enforcement in support of the Cult plan for a police-military state. Biden's fascist administration began a purge of 'wrong-thinkers' in the military which means anyone that is not on board with Woke. The Capitol Building was surrounded by a fence with razor wire and the Land of the Free was further symbolically and literally dismantled. The circle was completed with the installation of Biden and the exploitation of the QAnon Psyop.

America had never been so divided since the civil war of the 19th century, Pushbackers were isolated and dubbed terrorists and now, as was always going to happen, the Cult immediately set about deleting what little was left of freedom and transforming American society through a swish of the hand of the most controlled 'president' in American history leading (officially at least) the most extreme regime since the country was declared an independent state on July 4th, 1776. Biden issued undebated, dictatorial executive orders almost by the hour in his opening days in office across the whole spectrum of the Cult wish-list including diluting controls on the border with Mexico allowing thousands of migrants to illegally enter the United States to transform the demographics of America and import an election-changing number of perceived Democrat

voters. Then there were Biden deportation amnesties for the already illegally resident (estimated to be as high as 20 or even 30 million). A bill before Congress awarded American citizenship to anyone who could prove they had worked in agriculture for just 180 days in the previous two years as 'Big Ag' secured its slave labour long-term. There were the plans to add new states to the union such as Puerto Rico and making Washington DC a state. They are all parts of a plan to ensure that the Cult-owned Woke Democrats would be permanently in power.

Border – what border?

I have exposed in detail in other books how mass immigration into the United States and Europe is the work of Cult networks fuelled by the tens of billions spent to this and other ends by George Soros and his global Open Society (open borders) Foundations. The impact can be seen in America alone where the population has increased by *100 million* in little more than 30 years mostly through immigration. I wrote in *The Answer* that the plan was to have so many people crossing the southern border that the numbers become unstoppable and we are now there under Cult-owned Biden. El Salvador in Central America puts the scale of what is happening into context. A third of the population now lives in the United States, much of it illegally, and many more are on the way. The methodology is to crush Central and South American countries economically and spread violence through machete-wielding psychopathic gangs like MS-13 based in El Salvador and now operating in many American cities. Biden-imposed lax security at the southern border means that it is all but open. He said before his 'election' that he wanted to see a surge towards the border if he became president and that was the green light for people to do just that after election day to create the human disaster that followed for both America and the migrants. When that surge came the imbecilic Alexandria Ocasio-Cortez said it wasn't a 'surge' because they are 'children, not insurgents' and the term 'surge' (used by Biden) was a claim of 'white supremacists'.

This disingenuous lady may one day enter the realm of the most basic intelligence, but it won't be any time soon.

Sabbatians and the Cult are in the process of destroying America by importing violent people and gangs in among the genuine to terrorise American cities and by overwhelming services that cannot cope with the sheer volume of new arrivals. Something similar is happening in Europe as Western society in general is targeted for demographic and cultural transformation and upheaval. The plan demands violence and crime to create an environment of intimidation, fear and division and Soros has been funding the election of district attorneys across America who then stop prosecuting many crimes, reduce sentences for violent crimes and free as many violent criminals as they can. Sabbatians are creating the chaos from which order – their order – can respond in a classic Problem-Reaction-Solution. A Freemasonic moto says 'Ordo Ab Chao' (Order out of Chaos) and this is why the Cult is constantly creating chaos to impose a new 'order'. Here you have the reason the Cult is constantly creating chaos. The 'Covid' hoax can be seen with those entering the United States by plane being forced to take a 'Covid' test while migrants flooding through southern border processing facilities do not. Nothing is put in the way of mass migration and if that means ignoring the government's own 'Covid' rules then so be it. They know it's all bullshit anyway. Any pushback on this is denounced as 'racist' by Wokers and Sabbatian fronts like the ultra-Zionist Anti-Defamation League headed by the appalling Jonathan Greenblatt which at the same time argues that Israel should not give citizenship and voting rights to more Palestinian Arabs or the 'Jewish population' (in truth the Sabbatian network) will lose control of the country.

Society-changing numbers

Biden's masters have declared that countries like El Salvador are so dangerous that their people must be allowed into the United States for humanitarian reasons when there are fewer murders in large parts of many Central American countries than in US cities like

Baltimore. That is not to say Central America cannot be a dangerous place and Cult-controlled American governments have been making it so since way back, along with the dismantling of economies, in a long-term plan to drive people north into the United States. Parts of Central America are very dangerous, but in other areas the story is being greatly exaggerated to justify relaxing immigration criteria. Migrants are being offered free healthcare and education in the United States as another incentive to head for the border and there is no requirement to be financially independent before you can enter to prevent the resources of America being drained. You can't blame migrants for seeking what they believe will be a better life, but they are being played by the Cult for dark and nefarious ends. The numbers since Biden took office are huge. In February, 2021, more than 100,000 people were known to have tried to enter the US illegally through the southern border (it was 34,000 in the same month in 2020) and in March it was 170,000 – a 418 percent increase on March, 2020. These numbers are only known people, not the ones who get in unseen. The true figure for migrants illegally crossing the border in a single month was estimated by one congressman at 250,000 and that number will only rise under Biden's current policy. Gangs of murdering drug-running thugs that control the Mexican side of the border demand money – thousands of dollars – to let migrants cross the Rio Grande into America. At the same time gun battles are breaking out on the border several times a week between rival Mexican drug gangs (which now operate globally) who are equipped with sophisticated military-grade weapons, grenades and armoured vehicles. While the Capitol Building was being 'protected' from a non-existent 'threat' by thousands of troops, and others were still deployed at the time in the Cult Neocon war in Afghanistan, the southern border of America was left to its fate. This is not incompetence, it is cold calculation.

By March, 2021, there were 17,000 unaccompanied children held at border facilities and many of them are ensnared by people traffickers for paedophile rings and raped on their journey north to America. This is not conjecture – this is fact. Many of those designated

children are in reality teenage boys or older. Meanwhile Wokers posture their self-purity for encouraging poor and tragic people to come to America and face this nightmare both on the journey and at the border with the disgusting figure of House Speaker Nancy Pelosi giving disingenuous speeches about caring for migrants. The woman's evil. Wokers condemned Trump for having children in cages at the border (so did Obama, *Shhhh*), but now they are sleeping on the floor without access to a shower with one border facility 729 percent over capacity. The Biden insanity even proposed flying migrants from the southern border to the northern border with Canada for 'processing'. The whole shambles is being overseen by ultra-Zionist Secretary of Homeland Security, the moronic liar Alejandro Mayorkas, who banned news cameras at border facilities to stop Americans seeing what was happening. Mayorkas said there was not a ban on news crews; it was just that they were not allowed to film. Alongside him at Homeland Security is another ultra-Zionist Cass Sunstein appointed by Biden to oversee new immigration laws. Sunstein despises conspiracy researchers to the point where he suggests they should be banned or *taxed* for having such views. The man is not bonkers or anything. He's perfectly well-adjusted, but adjusted to what is the question. Criticise what is happening and you are a 'white supremacist' when earlier non-white immigrants also oppose the numbers which effect their lives and opportunities. Black people in poor areas are particularly damaged by uncontrolled immigration and the increased competition for work opportunities with those who will work for less. They are also losing voting power as Hispanics become more dominant in former black areas. It's a downward spiral for them while the billionaires behind the policy drone on about how much they care about black people and 'racism'. None of this is about compassion for migrants or black people – that's just wind and air. Migrants are instead being mercilessly exploited to transform America while the countries they leave are losing their future and the same is true in Europe. Mass immigration may now be the work of Woke Democrats, but it can be traced back to the 1986 Immigration Reform and Control Act (it

wasn't) signed into law by Republican hero President Ronald Reagan which gave amnesty to millions living in the United States illegally and other incentives for people to head for the southern border. Here we have the one-party state at work again.

Save me syndrome

Almost every aspect of what I have been exposing as the Cult agenda was on display in even the first days of 'Biden' with silencing of Pushbackers at the forefront of everything. A Renegade Mind will view the Trump years and QAnon in a very different light to their supporters and advocates as the dots are connected. The QAnon/Trump Psyop has given the Cult all it was looking for. We may not know how much, or little, that Trump realised he was being used, but that's a side issue. This pincer movement produced the desired outcome of dividing America and having Pushbackers isolated. To turn this around we have to look at new routes to empowerment which do not include handing our power to other people and groups through what I will call the 'Save Me Syndrome' – 'I want someone else to do it so that I don't have to'. We have seen this at work throughout human history and the QAnon/Trump Psyop is only the latest incarnation alongside all the others. Religion is an obvious expression of this when people look to a 'god' or priest to save them or tell them how to be saved and then there are 'save me' politicians like Trump. Politics is a diversion and not a 'saviour'. It is a means to block positive change, not make it possible.

Save Me Syndrome always comes with the same repeating theme of handing your power to whom or what you believe will save you while your real 'saviour' stares back from the mirror every morning. Renegade Minds are constantly vigilant in this regard and always asking the question 'What can I do?' rather than 'What can someone else do for me?' Gandhi was right when he said: 'You must be the change you want to see in the world.' We are indeed the people we have been waiting for. We are presented with a constant raft of reasons to concede that power to others and forget where the real power is. Humanity has the numbers and the Cult does not. It has to

use diversion and division to target the unstoppable power that comes from unity. Religions, governments, politicians, corporations, media, QAnon, are all different manifestations of this power-diversion and dilution. Refusing to give your power to governments and instead handing it to Trump and QAnon is not to take a new direction, but merely to recycle the old one with new names on the posters. I will explore this phenomenon as we proceed and how to break the cycles and recycles that got us here through the mists of repeating perception and so repeating history.

For now we shall turn to the most potent example in the entire human story of the consequences that follow when you give your power away. I am talking, of course, of the 'Covid' hoax.

CHAPTER FOUR

'Covid': Calculated catastrophe

Facts are threatening to those invested in fraud
DaShanne Stokes

We can easily unravel the real reason for the 'Covid pandemic' hoax by employing the Renegade Mind methodology that I have outlined this far. We'll start by comparing the long-planned Cult outcome with the 'Covid pandemic' outcome. Know the outcome and you'll see the journey.

I have highlighted the plan for the Hunger Games Society which has been in my books for so many years with the very few controlling the very many through ongoing dependency. To create this dependency it is essential to destroy independent livelihoods, businesses and employment to make the population reliant on the state (the Cult) for even the basics of life through a guaranteed pittance income. While independence of income remained these Cult ambitions would be thwarted. With this knowledge it was easy to see where the 'pandemic' hoax was going once talk of 'lockdowns' began and the closing of all but perceived 'essential' businesses to 'save' us from an alleged 'deadly virus'. Cult corporations like Amazon and Walmart were naturally considered 'essential' while mom and pop shops and stores had their doors closed by fascist decree. As a result with every new lockdown and new regulation more small and medium, even large businesses not owned by the Cult, went to the wall while Cult giants and their frontmen and women grew financially fatter by the second. Mom and pop were

denied an income and the right to earn a living and the wealth of people like Jeff Bezos (Amazon), Mark Zuckerberg (Facebook) and Sergei Brin and Larry Page (Google/Alphabet) have reached record levels. The Cult was increasing its own power through further dramatic concentrations of wealth while the competition was being destroyed and brought into a state of dependency. Lockdowns have been instigated to secure that very end and were never anything to do with health. My brother Paul spent 45 years building up a bus repair business, but lockdowns meant buses were running at a fraction of normal levels for months on end. Similar stories can told in their hundreds of millions worldwide. Efforts of a lifetime coldly destroyed by Cult multi-billionaires and their lackeys in government and law enforcement who continued to earn their living from the taxation of the people while denying the right of the same people to earn theirs. How different it would have been if those making and enforcing these decisions had to face the same financial hardships of those they affected, but they never do.

Gates of Hell

Behind it all in the full knowledge of what he is doing and why is the psychopathic figure of Cult operative Bill Gates. His puppet Tedros at the World Health Organization declared 'Covid' a pandemic in March, 2020. The WHO had changed the definition of a 'pandemic' in 2009 just a month before declaring the 'swine flu pandemic' which would not have been so under the previous definition. The same applies to 'Covid'. The definition had included… 'an infection by an infectious agent, occurring simultaneously in different countries, with a significant mortality rate relative to the proportion of the population infected'. The new definition removed the need for 'significant mortality'. The 'pandemic' has been fraudulent even down to the definition, but Gates demanded economy-destroying lockdowns, school closures, social distancing, mandatory masks, a 'vaccination' for every man, woman and child on the planet and severe consequences and restrictions for those that refused. Who gave him this power? The

Cult did which he serves like a little boy in short trousers doing what his daddy tells him. He and his psychopathic missus even smiled when they said that much worse was to come (what they knew was planned to come). Gates responded in the matter-of-fact way of all psychopaths to a question about the effect on the world economy of what he was doing:

> Well, it won't go to zero but it will shrink. Global GDP is probably going to take the biggest hit ever [Gates was smiling as he said this] … in my lifetime this will be the greatest economic hit. But you don't have a choice. People act as if you have a choice. People don't feel like going to the stadium when they might get infected … People are deeply affected by seeing these stats, by knowing they could be part of the transmission chain, old people, their parents and grandparents, could be affected by this, and so you don't get to say ignore what is going on here.
>
> There will be the ability to open up, particularly in rich countries, if things are done well over the next few months, but for the world at large normalcy only returns when we have largely vaccinated the entire population.

The man has no compassion or empathy. How could he when he's a psychopath like all Cult players? My own view is that even beyond that he is very seriously mentally ill. Look in his eyes and you can see this along with his crazy flailing arms. You don't do what he has done to the world population since the start of 2020 unless you are mentally ill and at the most extreme end of psychopathic. You especially don't do it when to you know, as we shall see, that cases and deaths from 'Covid' are fakery and a product of monumental figure massaging. 'These stats' that Gates referred to are based on a 'test' that's not testing for the 'virus' as he has known all along. He made his fortune with big Cult support as an infamously ruthless software salesman and now buys global control of 'health' (death) policy without the population he affects having any say. It's a breathtaking outrage. Gates talked about people being deeply affected by fear of 'Covid' when that was because of *him* and his global network lying to them minute-by-minute supported by a lying media that he seriously influences and funds to the tune of hundreds of millions. He's handed big sums to media operations including the BBC, NBC, Al Jazeera, Univision, *PBS NewsHour*,

ProPublica, National Journal, The Guardian, The Financial Times, The Atlantic, Texas Tribune, USA Today publisher Gannett, *Washington Monthly, Le Monde,* Center for Investigative Reporting, Pulitzer Center on Crisis Reporting, National Press Foundation, International Center for Journalists, Solutions Journalism Network, the Poynter Institute for Media Studies, and many more. Gates is everywhere in the 'Covid' hoax and the man must go to prison – or a mental facility – for the rest of his life and his money distributed to those he has taken such enormous psychopathic pleasure in crushing.

The Muscle

The Hunger Games global structure demands a police-military state – a fusion of the two into one force – which viciously imposes the will of the Cult on the population and protects the Cult from public rebellion. In that regard, too, the 'Covid' hoax just keeps on giving. Often unlawful, ridiculous and contradictory 'Covid' rules and regulations have been policed across the world by moronic automatons and psychopaths made faceless by face-nappy masks and acting like the Nazi SS and fascist blackshirts and brownshirts of Hitler and Mussolini. The smallest departure from the rules decreed by the psychos in government and their clueless gofers were jumped upon by the face-nappy fascists. Brutality against public protestors soon became commonplace even on girls, women and old people as the brave men with the batons – the Face-Nappies as I call them – broke up peaceful protests and handed out fines like confetti to people who couldn't earn a living let alone pay hundreds of pounds for what was once an accepted human right. Robot Face-Nappies of Nottingham police in the English East Midlands fined one group £11,000 for attending a child's birthday party. For decades I charted the transformation of law enforcement as genuine, decent officers were replaced with psychopaths and the brain dead who would happily and brutally do whatever their masters told them. Now they were let loose on the public and I would emphasise the point that none of this just happened. The step-by-step change in the dynamic between police and public was orchestrated from the shadows by

those who knew where this was all going and the same with the perceptual reframing of those in all levels of authority and official administration through 'training courses' by organisations such as Common Purpose which was created in the late 1980s and given a massive boost in Blair era Britain until it became a global phenomenon. Supposed public 'servants' began to view the population as the enemy and the same was true of the police. This was the start of the explosion of behaviour manipulation organisations and networks preparing for the all-war on the human psyche unleashed with the dawn of 2020. I will go into more detail about this later in the book because it is a core part of what is happening.

Police desecrated beauty spots to deter people gathering and arrested women for walking in the countryside alone 'too far' from their homes. We had arrogant, clueless sergeants in the Isle of Wight police where I live posting on Facebook what they insisted the population must do or else. A schoolmaster sergeant called Radford looked young enough for me to ask if his mother knew he was out, but he was posting what he *expected* people to do while a Sergeant Wilkinson boasted about fining lads for meeting in a McDonald's car park where they went to get a lockdown takeaway. Wilkinson added that he had even cancelled their order. What a pair of prats these people are and yet they have increasingly become the norm among Jackboot Johnson's Yellowshirts once known as the British police. This was the theme all over the world with police savagery common during lockdown protests in the United States, the Netherlands, and the fascist state of Victoria in Australia under its tyrannical and again moronic premier Daniel Andrews. Amazing how tyrannical and moronic tend to work as a team and the same combination could be seen across America as arrogant, narcissistic Woke governors and mayors such as Gavin Newsom (California), Andrew Cuomo (New York), Gretchen Whitmer (Michigan), Lori Lightfoot (Chicago) and Eric Garcetti (Los Angeles) did their Nazi and Stalin impressions with the full support of the compliant brutality of their enforcers in uniform as they arrested small business owners defying

fascist shutdown orders and took them to jail in ankle shackles and handcuffs. This happened to bistro owner Marlena Pavlos-Hackney in Gretchen Whitmer's fascist state of Michigan when police arrived to enforce an order by a state-owned judge for 'putting the community at risk' at a time when other states like Texas were dropping restrictions and migrants were pouring across the southern border without any 'Covid' questions at all. I'm sure there are many officers appalled by what they are ordered to do, but not nearly enough of them. If they were truly appalled they would not do it. As the months passed every opportunity was taken to have the military involved to make their presence on the streets ever more familiar and 'normal' for the longer-term goal of police-military fusion.

Another crucial element to the Hunger Games enforcement network has been encouraging the public to report neighbours and others for 'breaking the lockdown rules'. The group faced with £11,000 in fines at the child's birthday party would have been dobbed-in by a neighbour with a brain the size of a pea. The technique was most famously employed by the Stasi secret police in communist East Germany who had public informants placed throughout the population. A police chief in the UK says his force doesn't need to carry out 'Covid' patrols when they are flooded with so many calls from the public reporting other people for visiting the beach. Dorset police chief James Vaughan said people were so enthusiastic about snitching on their fellow humans they were now operating as an auxiliary arm of the police: 'We are still getting around 400 reports a week from the public, so we will respond to reports …We won't need to be doing hotspot patrols because people are very quick to pick the phone up and tell us.' Vaughan didn't say that this is a pillar of all tyrannies of whatever complexion and the means to hugely extend the reach of enforcement while spreading distrust among the people and making them wary of doing anything that might get them reported. Those narcissistic Isle of Wight sergeants Radford and Wilkinson never fail to add a link to their Facebook posts where the public can inform on their fellow slaves.

Neither would be self-aware enough to realise they were imitating the Stasi which they might well never have heard of. Government psychologists that I will expose later laid out a policy to turn communities against each other in the same way.

A coincidence? Yep, and I can knit fog

I knew from the start of the alleged pandemic that this was a Cult operation. It presented limitless potential to rapidly advance the Cult agenda and exploit manipulated fear to demand that every man, woman and child on the planet was 'vaccinated' in a process never used on humans before which infuses self-replicating *synthetic* material into human cells. Remember the plan to transform the human body from a biological to a synthetic biological state. I'll deal with the 'vaccine' (that's not actually a vaccine) when I focus on the genetic agenda. Enough to say here that mass global 'vaccination' justified by this 'new virus' set alarms ringing after 30 years of tracking these people and their methods. The 'Covid' hoax officially beginning in China was also a big red flag for reasons I will be explaining. The agenda potential was so enormous that I could dismiss any idea that the 'virus' appeared naturally. Major happenings with major agenda implications never occur without Cult involvement in making them happen. My questions were twofold in early 2020 as the media began its campaign to induce global fear and hysteria: Was this alleged infectious agent released on purpose by the Cult or did it even exist at all? I then did what I always do in these situations. I sat, observed and waited to see where the evidence and information would take me. By March and early April synchronicity was strongly – and ever more so since then – pointing me in the direction of *there is no 'virus'*. I went public on that with derision even from swathes of the alternative media that voiced a scenario that the Chinese government released the 'virus' in league with Deep State elements in the United States from a top-level bio-lab in Wuhan where the 'virus' is said to have first appeared. I looked at that possibility, but I didn't buy it for several reasons. Deaths from the 'virus' did not in any way match what they

would have been with a 'deadly bioweapon' and it is much more effective if you sell the *illusion* of an infectious agent rather than having a real one unless you can control through injection who has it and who doesn't. Otherwise you lose control of events. A made-up 'virus' gives you a blank sheet of paper on which you can make it do whatever you like and have any symptoms or mutant 'variants' you choose to add while a real infectious agent would limit you to what it actually does. A phantom disease allows you to have endless ludicrous 'studies' on the 'Covid' dollar to widen the perceived impact by inventing ever more 'at risk' groups including one study which said those who walk slowly may be almost four times more likely to die from the 'virus'. People are in psychiatric wards for less.

A real 'deadly bioweapon' can take out people in the hierarchy that are not part of the Cult, but essential to its operation. Obviously they don't want that. Releasing a real disease means you immediately lose control of it. Releasing an illusory one means you don't. Again it's vital that people are extra careful when dealing with what they want to hear. A bioweapon unleashed from a Chinese laboratory in collusion with the American Deep State may fit a conspiracy narrative, but is it true? Would it not be far more effective to use the excuse of a 'virus' to justify the real bioweapon – the 'vaccine'? That way your disease agent does not have to be transmitted and arrives directly through a syringe. I saw a French virologist Luc Montagnier quoted in the alternative media as saying he had discovered that the alleged 'new' severe acute respiratory syndrome coronavirus , or SARS-CoV-2, was made artificially and included elements of the human immunodeficiency 'virus' (HIV) and a parasite that causes malaria. SARS-CoV-2 is alleged to trigger an alleged illness called Covid-19. I remembered Montagnier's name from my research years before into claims that an HIV 'retrovirus' causes AIDs – claims that were demolished by Berkeley virologist Peter Duesberg who showed that no one had ever proved that HIV causes acquired immunodeficiency syndrome or AIDS. Claims that become accepted as fact, publicly and medically, with no proof whatsoever are an ever-recurring story that profoundly applies to

'Covid'. Nevertheless, despite the lack of proof, Montagnier's team at the Pasteur Institute in Paris had a long dispute with American researcher Robert Gallo over which of them discovered and isolated the HIV 'virus' and with *no evidence* found it to cause AIDS. You will see later that there is also no evidence that any 'virus' causes any disease or that there is even such a thing as a 'virus' in the way it is said to exist. The claim to have 'isolated' the HIV 'virus' will be presented in its real context as we come to the shocking story – and it is a story – of SARS-CoV-2 and so will Montagnier's assertion that he identified the full SARS-CoV-2 genome.

Hoax in the making

We can pick up the 'Covid' story in 2010 and the publication by the Rockefeller Foundation of a document called 'Scenarios for the Future of Technology and International Development'. The inner circle of the Rockefeller family has been serving the Cult since John D. Rockefeller (1839-1937) made his fortune with Standard Oil. It is less well known that the same Rockefeller – the Bill Gates of his day – was responsible for establishing what is now referred to as 'Big Pharma', the global network of pharmaceutical companies that make outrageous profits dispensing scalpel and drug 'medicine' and are obsessed with pumping vaccines in ever-increasing number into as many human arms and backsides as possible. John D. Rockefeller was the driving force behind the creation of the 'education' system in the United States and elsewhere specifically designed to program the perceptions of generations thereafter. The Rockefeller family donated exceptionally valuable land in New York for the United Nations building and were central in establishing the World Health Organization in 1948 as an agency of the UN which was created from the start as a Trojan horse and stalking horse for world government. Now enter Bill Gates. His family and the Rockefellers have long been extremely close and I have seen genealogy which claims that if you go back far enough the two families fuse into the same bloodline. Gates has said that the Bill and Melinda Gates Foundation was inspired by the Rockefeller Foundation and why not

when both are serving the same Cult? Major tax-exempt foundations are overwhelmingly criminal enterprises in which Cult assets fund the Cult agenda in the guise of 'philanthropy' while avoiding tax in the process. Cult operatives can become mega-rich in their role of front men and women for the psychopaths at the inner core and they, too, have to be psychopaths to knowingly serve such evil. Part of the deal is that a big percentage of the wealth gleaned from representing the Cult has to be spent advancing the ambitions of the Cult and hence you have the Rockefeller Foundation, Bill and Melinda Gates Foundation (and *so* many more) and people like George Soros with his global Open Society Foundations spending their billions in pursuit of global Cult control. Gates is a global public face of the Cult with his interventions in world affairs including Big Tech influence; a central role in the 'Covid' and 'vaccine' scam; promotion of the climate change shakedown; manipulation of education; geoengineering of the skies; and his food-control agenda as the biggest owner of farmland in America, his GMO promotion and through other means. As one writer said: 'Gates monopolizes or wields disproportionate influence over the tech industry, global health and vaccines, agriculture and food policy (including biopiracy and fake food), weather modification and other climate technologies, surveillance, education and media.' The almost limitless wealth secured through Microsoft and other not-allowed-to-fail ventures (including vaccines) has been ploughed into a long, long list of Cult projects designed to enslave the entire human race. Gates and the Rockefellers have been working as one unit with the Rockefeller-established World Health Organization leading global 'Covid' policy controlled by Gates through his mouth-piece Tedros. Gates became the WHO's biggest funder when Trump announced that the American government would cease its donations, but Biden immediately said he would restore the money when he took office in January, 2021. The Gates Foundation (the Cult) owns through limitless funding the world health system and the major players across the globe in the 'Covid' hoax.

Okay, with that background we return to that Rockefeller Foundation document of 2010 headed 'Scenarios for the Future of Technology and International Development' and its 'imaginary' epidemic of a virulent and deadly influenza strain which infected 20 percent of the global population and killed eight million in seven months. The Rockefeller scenario was that the epidemic destroyed economies, closed shops, offices and other businesses and led to governments imposing fierce rules and restrictions that included mandatory wearing of face masks and body-temperature checks to enter communal spaces like railway stations and supermarkets. The document predicted that even after the height of the Rockefeller-envisaged epidemic the authoritarian rule would continue to deal with further pandemics, transnational terrorism, environmental crises and rising poverty. Now you may think that the Rockefellers are our modern-day seers or alternatively, and rather more likely, that they well knew what was planned a few years further on. Fascism had to be imposed, you see, to 'protect citizens from risk and exposure'. The Rockefeller scenario document said:

During the pandemic, national leaders around the world flexed their authority and imposed airtight rules and restrictions, from the mandatory wearing of face masks to body-temperature checks at the entries to communal spaces like train stations and supermarkets. Even after the pandemic faded, this more authoritarian control and oversight of citizens and their activities stuck and even intensified. In order to protect themselves from the spread of increasingly global problems – from pandemics and transnational terrorism to environmental crises and rising poverty – leaders around the world took a firmer grip on power.

At first, the notion of a more controlled world gained wide acceptance and approval. Citizens willingly gave up some of their sovereignty – and their privacy – to more paternalistic states in exchange for greater safety and stability. Citizens were more tolerant, and even eager, for top-down direction and oversight, and national leaders had more latitude to impose order in the ways they saw fit.

In developed countries, this heightened oversight took many forms: biometric IDs for all citizens, for example, and tighter regulation of key industries whose stability was deemed vital to national interests. In many developed countries, enforced cooperation with a suite of new regulations and agreements slowly but steadily restored both order and, importantly, economic growth.

There we have the prophetic Rockefellers in 2010 and three years later came their paper for the Global Health Summit in Beijing, China, when government representatives, the private sector, international organisations and groups met to discuss the next 100 years of 'global health'. The Rockefeller Foundation-funded paper was called 'Dreaming the Future of Health for the Next 100 Years and more prophecy ensued as it described a dystopian future: 'The abundance of data, digitally tracking and linking people may mean the 'death of privacy' and may replace physical interaction with transient, virtual connection, generating isolation and raising questions of how values are shaped in virtual networks.' Next in the 'Covid' hoax preparation sequence came a 'table top' simulation in 2018 for another 'imaginary' pandemic of a disease called Clade X which was said to kill 900 million people. The exercise was organised by the Gates-funded Johns Hopkins University's Center for Health Security in the United States and this is the very same university that has been compiling the disgustingly and systematically erroneous global figures for 'Covid' cases and deaths. Similar Johns Hopkins health crisis scenarios have included the Dark Winter exercise in 2001 and Atlantic Storm in 2005.

Nostradamus 201

For sheer predictive genius look no further prophecy-watchers than the Bill Gates-funded Event 201 held only six weeks before the 'coronavirus pandemic' is supposed to have broken out in China and Event 201 was based on a scenario of a global 'coronavirus pandemic'. Melinda Gates, the great man's missus, told the BBC that he had 'prepared for years' for a coronavirus pandemic which told us what we already knew. Nostradamugates had predicted in a TED talk in 2015 that a pandemic was coming that would kill a lot of people and demolish the world economy. My god, the man is a machine – possibly even literally. Now here he was only weeks before the real thing funding just such a simulated scenario and involving his friends and associates at Johns Hopkins, the World Economic Forum Cult-front of Klaus Schwab, the United Nations,

Johnson & Johnson, major banks, and officials from China and the Centers for Disease Control in the United States. What synchronicity – Johns Hopkins would go on to compile the fraudulent 'Covid' figures, the World Economic Forum and Schwab would push the 'Great Reset' in response to 'Covid', the Centers for Disease Control would be at the forefront of 'Covid' policy in the United States, Johnson & Johnson would produce a 'Covid vaccine', and everything would officially start just weeks later in China. Spooky, eh? They were even accurate in creating a simulation of a 'virus' pandemic because the 'real thing' would also be a simulation. Event 201 was not an exercise preparing for something that might happen; it was a rehearsal for what those in control knew was *going* to happen and very shortly. Hours of this simulation were posted on the Internet and the various themes and responses mirrored what would soon be imposed to transform human society. News stories were inserted and what they said would be commonplace a few weeks later with still more prophecy perfection. Much discussion focused on the need to deal with misinformation and the 'anti-vax movement' which is exactly what happened when the 'virus' arrived – was said to have arrived – in the West.

Cult-owned social media banned criticism and exposure of the official 'virus' narrative and when I said there *was* no 'virus' in early April, 2020, I was banned by one platform after another including YouTube, Facebook and later Twitter. The mainstream broadcast media in Britain was in effect banned from interviewing me by the Tony-Blair-created government broadcasting censor Ofcom headed by career government bureaucrat Melanie Dawes who was appointed just as the 'virus' hoax was about to play out in January, 2020. At the same time the Ickonic media platform was using Vimeo, another ultra-Zionist-owned operation, while our own player was being created and they deleted in an instant hundreds of videos, documentaries, series and shows to confirm their unbelievable vindictiveness. We had copies, of course, and they had to be restored one by one when our player was ready. These people have no class. Sabbatian Facebook promised free advertisements for the Gates-

controlled World Health Organization narrative while deleting 'false claims and conspiracy theories' to stop 'misinformation' about the alleged coronavirus. All these responses could be seen just a short while earlier in the scenarios of Event 201. Extreme censorship was absolutely crucial for the Cult because the official story was so ridiculous and unsupportable by the evidence that it could never survive open debate and the free-flow of information and opinion. If you can't win a debate then don't have one is the Cult's approach throughout history. Facebook's little boy front man – front boy – Mark Zuckerberg equated 'credible and accurate information' with official sources and exposing their lies with 'misinformation'.

Silencing those that can see

The censorship dynamic of Event 201 is now the norm with an army of narrative-supporting 'fact-checker' organisations whose entire reason for being is to tell the public that official narratives are true and those exposing them are lying. One of the most appalling of these 'fact-checkers' is called NewsGuard founded by ultra-Zionist Americans Gordon Crovitz and Steven Brill. Crovitz is a former publisher of *The Wall Street Journal*, former Executive Vice President of Dow Jones, a member of the Council on Foreign Relations (CFR), and on the board of the American Association of Rhodes Scholars. The CFR and Rhodes Scholarships, named after Rothschild agent Cecil Rhodes who plundered the gold and diamonds of South Africa for his masters and the Cult, have featured widely in my books. NewsGuard don't seem to like me for some reason – I really can't think why – and they have done all they can to have me censored and discredited which is, to quote an old British politician, like being savaged by a dead sheep. They are, however, like all in the censorship network, very well connected and funded by organisations themselves funded by, or connected to, Bill Gates. As you would expect with anything associated with Gates NewsGuard has an offshoot called HealthGuard which 'fights online health care hoaxes'. How very kind. Somehow the NewsGuard European Managing Director Anna-Sophie Harling, a remarkably young-

looking woman with no broadcasting experience and little hands-on work in journalism, has somehow secured a position on the 'Content Board' of UK government broadcast censor Ofcom. An executive of an organisation seeking to discredit dissidents of the official narratives is making decisions for the government broadcast 'regulator' about content?? Another appalling 'fact-checker' is Full Fact funded by George Soros and global censors Google and Facebook.

It's amazing how many activists in the 'fact-checking', 'anti-hate', arena turn up in government-related positions – people like UK Labour Party activist Imran Ahmed who heads the Center for Countering Digital Hate founded by people like Morgan McSweeney, now chief of staff to the Labour Party's hapless and useless 'leader' Keir Starmer. Digital Hate – which is what it really is – uses the American spelling of Center to betray its connection to a transatlantic network of similar organisations which in 2020 shapeshifted from attacking people for 'hate' to attacking them for questioning the 'Covid' hoax and the dangers of the 'Covid vaccine'. It's just a coincidence, you understand. This is one of Imran Ahmed's hysterical statements: 'I would go beyond calling anti-vaxxers conspiracy theorists to say they are an extremist group that pose a national security risk.' No one could ever accuse this prat of understatement and he's including in that those parents who are now against vaccines after their children were damaged for life or killed by them. He's such a nice man. Ahmed does the rounds of the Woke media getting soft-ball questions from spineless 'journalists' who never ask what right he has to campaign to destroy the freedom of speech of others while he demands it for himself. There also seems to be an overrepresentation in Ofcom of people connected to the narrative-worshipping BBC. This incredible global network of narrative-support was super-vital when the 'Covid' hoax was played in the light of the mega-whopper lies that have to be defended from the spotlight cast by the most basic intelligence.

Setting the scene

The Cult plays the long game and proceeds step-by-step ensuring that everything is in place before major cards are played and they don't come any bigger than the 'Covid' hoax. The psychopaths can't handle events where the outcome isn't certain and as little as possible – preferably nothing – is left to chance. Politicians, government and medical officials who would follow direction were brought to illusory power in advance by the Cult web whether on the national stage or others like state governors and mayors of America. For decades the dynamic between officialdom, law enforcement and the public was changed from one of service to one of control and dictatorship. Behaviour manipulation networks established within government were waiting to impose the coming 'Covid' rules and regulations specifically designed to subdue and rewire the psyche of the people in the guise of protecting health. These included in the UK the Behavioural Insights Team part-owned by the British government Cabinet Office; the Scientific Pandemic Insights Group on Behaviours (SPI-B); and a whole web of intelligence and military groups seeking to direct the conversation on social media and control the narrative. Among them are the cyberwarfare (on the people) 77th Brigade of the British military which is also coordinated through the Cabinet Office as civilian and military leadership continues to combine in what they call the Fusion Doctrine. The 77th Brigade is a British equivalent of the infamous Israeli (Sabbatian) military cyberwarfare and Internet manipulation operation Unit 8200 which I expose at length in *The Trigger*. Also carefully in place were the medical and science advisers to government – many on the payroll past or present of Bill Gates – and a whole alternative structure of unelected government stood by to take control when elected parliaments were effectively closed down once the 'Covid' card was slammed on the table. The structure I have described here and so much more was installed in every major country through the Cult networks. The top-down control hierarchy looks like this: The Cult – Cult-owned Gates – the World Health Organization and Tedros – Gates-funded or controlled chief medical officers and science 'advisers' (dictators) in each country –

political 'leaders'– law enforcement – The People. Through this simple global communication and enforcement structure the policy of the Cult could be imposed on virtually the entire human population so long as they acquiesced to the fascism. With everything in place it was time for the button to be pressed in late 2019/early 2020.

These were the prime goals the Cult had to secure for its will to prevail:

1) Locking down economies, closing all but designated 'essential' businesses (Cult-owned corporations were 'essential'), and putting the population under house arrest was an imperative to destroy independent income and employment and ensure dependency on the Cult-controlled state in the Hunger Games Society. Lockdowns had to be established as the global blueprint from the start to respond to the 'virus' and followed by pretty much the entire world.

2) The global population had to be terrified into believing in a deadly 'virus' that didn't actually exist so they would unquestioningly obey authority in the belief that authority must know how best to protect them and their families. Software salesman Gates would suddenly morph into the world's health expert and be promoted as such by the Cult-owned media.

3) A method of testing that wasn't testing for the 'virus', but was only claimed to be, had to be in place to provide the illusion of 'cases' and subsequent 'deaths' that had a very different cause to the 'Covid-19' that would be scribbled on the death certificate.

4) Because there was no 'virus' and the great majority testing positive with a test not testing for the 'virus' would have no symptoms of anything the lie had to be sold that people without symptoms (without the 'virus') could still pass it on to others. This was crucial to justify for the first time quarantining – house arresting – healthy people. Without this the economy-destroying lockdown of *everybody* could not have been credibly sold.

5) The 'saviour' had to be seen as a vaccine which beyond evil drug companies were working like angels of mercy to develop as quickly as possible, with all corners cut, to save the day. The public must absolutely not know that the 'vaccine' had nothing to do with a 'virus' or that the contents were ready and waiting with a very different motive long before the 'Covid' card was even lifted from the pack.

I said in March, 2020, that the 'vaccine' would have been created way ahead of the 'Covid' hoax which justified its use and the following December an article in the New York *Intelligencer* magazine said the Moderna 'vaccine' had been 'designed' by

January, 2020. This was 'before China had even acknowledged that the disease could be transmitted from human to human, more than a week before the first confirmed coronavirus case in the United States'. The article said that by the time the first American death was announced a month later 'the vaccine had already been manufactured and shipped to the National Institutes of Health for the beginning of its Phase I clinical trial'. The 'vaccine' was actually 'designed' long before that although even with this timescale you would expect the article to ask how on earth it could have been done that quickly. Instead it asked why the 'vaccine' had not been rolled out then and not months later. Journalism in the mainstream is truly dead. I am going to detail in the next chapter why the 'virus' has never existed and how a hoax on that scale was possible, but first the foundation on which the Big Lie of 'Covid' was built.

The test that doesn't test

Fraudulent 'testing' is the bottom line of the whole 'Covid' hoax and was the means by which a 'virus' that did not exist *appeared* to exist. They could only achieve this magic trick by using a test not testing for the 'virus'. To use a test that *was* testing for the 'virus' would mean that every test would come back negative given there was no 'virus'. They chose to exploit something called the RT-PCR test invented by American biochemist Kary Mullis in the 1980s who said publicly that his PCR test … *cannot detect infectious disease*. Yes, the 'test' used worldwide to detect infectious 'Covid' to produce all the illusory 'cases' and 'deaths' compiled by Johns Hopkins and others *cannot detect infectious disease*. This fact came from the mouth of the man who invented PCR and was awarded the Nobel Prize in Chemistry in 1993 for doing so. Sadly, and incredibly conveniently for the Cult, Mullis died in August, 2019, at the age of 74 just before his test would be fraudulently used to unleash fascism on the world. He was said to have died from pneumonia which was an irony in itself. A few months later he would have had 'Covid-19' on his death certificate. I say the timing of his death was convenient because had he lived Mullis, a brilliant, honest and decent man, would have been

vociferously speaking out against the use of his test to detect 'Covid' when it was never designed, or able, to do that. I know that to be true given that Mullis made the same point when his test was used to 'detect' – not detect – HIV. He had been seriously critical of the Gallo/Montagnier claim to have isolated the HIV 'virus' and shown it to cause AIDS for which Mullis said there was no evidence. AIDS is actually not a disease but a series of diseases from which people die all the time. When they die from those *same diseases* after a positive 'test' for HIV then AIDS goes on their death certificate. I think I've heard that before somewhere. Countries instigated a policy with 'Covid' that anyone who tested positive with a test not testing for the 'virus' and died of any other cause within 28 days and even longer 'Covid-19' had to go on the death certificate. Cases have come from the test that can't test for infectious disease and the deaths are those who have died of *anything* after testing positive with a test not testing for the 'virus'. I'll have much more later about the death certificate scandal.

Mullis was deeply dismissive of the now US 'Covid' star Anthony Fauci who he said was a liar who didn't know anything about anything – 'and I would say that to his face – nothing.' He said of Fauci: 'The man thinks he can take a blood sample, put it in an electron microscope and if it's got a virus in there you'll know it – he doesn't understand electron microscopy and he doesn't understand medicine and shouldn't be in a position like he's in.' That position, terrifyingly, has made him the decider of 'Covid' fascism policy on behalf of the Cult in his role as director since 1984 of the National Institute of Allergy and Infectious Diseases (NIAID) while his record of being wrong is laughable; but being wrong, so long as it's the *right kind* of wrong, is why the Cult loves him. He'll say anything the Cult tells him to say. Fauci was made Chief Medical Adviser to the President immediately Biden took office. Biden was installed in the White House by Cult manipulation and one of his first decisions was to elevate Fauci to a position of even more control. This is a coincidence? Yes, and I identify as a flamenco dancer called Lola. How does such an incompetent criminal like Fauci remain in that

pivotal position in American health since *the 1980s*? When you serve the Cult it looks after you until you are surplus to requirements. Kary Mullis said prophetically of Fauci and his like: 'Those guys have an agenda and it's not an agenda we would like them to have … they make their own rules, they change them when they want to, and Tony Fauci does not mind going on television in front of the people who pay his salary and lie directly into the camera.' Fauci has done that almost daily since the 'Covid' hoax began. Lying is in Fauci's DNA. To make the situation crystal clear about the PCR test this is a direct quote from its inventor Kary Mullis:

> It [the PCR test] doesn't tell you that you're sick and doesn't tell you that the thing you ended up with was really going to hurt you ...'

Ask yourself why governments and medical systems the world over have been using this very test to decide who is 'infected' with the SARS-CoV-2 'virus' and the alleged disease it allegedly causes, 'Covid-19'. The answer to that question will tell you what has been going on. By the way, here's a little show-stopper – the 'new' SARS-CoV-2 'virus' was 'identified' as such right from the start using … *the PCR test not testing for the 'virus'*. If you are new to this and find that shocking then stick around. I have hardly started yet. Even worse, other 'tests', like the 'Lateral Flow Device' (LFD), are considered so useless that they have to be *confirmed* by the PCR test! Leaked emails written by Ben Dyson, adviser to UK 'Health' Secretary Matt Hancock, said they were 'dangerously unreliable'. Dyson, executive director of strategy at the Department of Health, wrote: 'As of today, someone who gets a positive LFD result in (say) London has at best a 25 per cent chance of it being a true positive, but if it is a self-reported test potentially as low as 10 per cent (on an optimistic assumption about specificity) or as low as 2 per cent (on a more pessimistic assumption).' These are the 'tests' that schoolchildren and the public are being urged to have twice a week or more and have to isolate if they get a positive. Each fake positive goes in the statistics as a 'case' no matter how ludicrously inaccurate and the

'cases' drive lockdown, masks and the pressure to 'vaccinate'. The government said in response to the email leak that the 'tests' were accurate which confirmed yet again what shocking bloody liars they are. The real false positive rate is *100 percent* as we'll see. In another 'you couldn't make it up' the UK government agreed to pay £2.8 billion to California's Innova Medical Group to supply the irrelevant lateral flow tests. The company's primary test-making centre is in China. Innova Medical Group, established in March, 2020, is owned by Pasaca Capital Inc, chaired by Chinese-American millionaire Charles Huang who was born in Wuhan.

How it works – and how it doesn't

The RT-PCR test, known by its full title of Polymerase chain reaction, is used across the world to make millions, even billions, of copies of a DNA/RNA genetic information sample. The process is called 'amplification' and means that a tiny sample of genetic material is amplified to bring out the detailed content. I stress that it is not testing for an infectious disease. It is simply amplifying a sample of genetic material. In the words of Kary Mullis: 'PCR is … just a process that's used to make a whole lot of something out of something.' To emphasise the point companies that make the PCR tests circulated around the world to 'test' for 'Covid' warn on the box that it can't be used to detect 'Covid' or infectious disease and is for research purposes only. It's okay, rest for a minute and you'll be fine. This is the test that produces the 'cases' and 'deaths' that have been used to destroy human society. All those global and national medical and scientific 'experts' demanding this destruction to 'save us' *KNOW* that the test is not testing for the 'virus' and the cases and deaths they claim to be real are an almost unimaginable fraud. Every one of them and so many others including politicians and psychopaths like Gates and Tedros must be brought before Nuremburg-type trials and jailed for the rest of their lives. The more the genetic sample is amplified by PCR the more elements of that material become sensitive to the test and by that I don't mean sensitive for a 'virus' but for elements of the genetic material which

is *naturally* in the body or relates to remnants of old conditions of various kinds lying dormant and causing no disease. Once the amplification of the PCR reaches a certain level *everyone* will test positive. So much of the material has been made sensitive to the test that everyone will have some part of it in their body. Even lying criminals like Fauci have said that once PCR amplifications pass 35 cycles everything will be a false positive that cannot be trusted for the reasons I have described. I say, like many proper doctors and scientists, that 100 percent of the 'positives' are false, but let's just go with Fauci for a moment.

He says that any amplification over 35 cycles will produce false positives and yet the US Centers for Disease Control (CDC) and Food and Drug Administration (FDA) have recommended up to *40 cycles* and the National Health Service (NHS) in Britain admitted in an internal document for staff that it was using *45 cycles* of amplification. A long list of other countries has been doing the same and at least one 'testing' laboratory has been using *50 cycles*. Have you ever heard a doctor, medical 'expert' or the media ask what level of amplification has been used to claim a 'positive'. The 'test' comes back 'positive' and so you have the 'virus', end of story. Now we can see how the government in Tanzania could send off samples from a goat and a pawpaw fruit under human names and both came back positive for 'Covid-19'. Tanzania president John Magufuli mocked the 'Covid' hysteria, the PCR test and masks and refused to import the DNA-manipulating 'vaccine'. The Cult hated him and an article sponsored by the Bill Gates Foundation appeared in the London *Guardian* in February, 2021, headed 'It's time for Africa to rein in Tanzania's anti-vaxxer president'. Well, 'reined in' he shortly was. Magufuli appeared in good health, but then, in March, 2021, he was dead at 61 from 'heart failure'. He was replaced by Samia Hassan Suhulu who is connected to Klaus Schwab's World Economic Forum and she immediately reversed Magufuli's 'Covid' policy. A sample of cola tested positive for 'Covid' with the PCR test in Germany while American actress and singer-songwriter Erykah Badu tested positive in one nostril and negative in the other. Footballer Ronaldo called

the PCR test 'bullshit' after testing positive three times and being forced to quarantine and miss matches when there was nothing wrong with him. The mantra from Tedros at the World Health Organization and national governments (same thing) has been test, test, test. They know that the more tests they can generate the more fake 'cases' they have which go on to become 'deaths' in ways I am coming to. The UK government has its Operation Moonshot planned to test multiple millions every day in workplaces and schools with free tests for everyone to use twice a week at home in line with the Cult plan from the start to make testing part of life. A government advertisement for an 'Interim Head of Asymptomatic Testing Communication' said the job included responsibility for delivering a 'communications strategy' (propaganda) 'to support the expansion of asymptomatic testing that *'normalises testing as part of everyday life*'. More tests means more fake 'cases', 'deaths' and fascism. I have heard of, and from, many people who booked a test, couldn't turn up, and yet got a positive result through the post for a test they'd never even had. The whole thing is crazy, but for the Cult there's method in the madness. Controlling and manipulating the level of amplification of the test means the authorities can control whenever they want the number of apparent 'cases' and 'deaths'. If they want to justify more fascist lockdown and destruction of livelihoods they keep the amplification high. If they want to give the illusion that lockdowns and the 'vaccine' are working then they lower the amplification and 'cases' and 'deaths' will appear to fall. In January, 2021, the Cult-owned World Health Organization suddenly warned laboratories about over-amplification of the test and to lower the threshold. Suddenly headlines began appearing such as: 'Why ARE "Covid" cases plummeting?' This was just when the vaccine rollout was underway and I had predicted months before they would make cases appear to fall through amplification tampering when the 'vaccine' came. These people are so predictable.

Cow vaccines?

The question must be asked of what is on the test swabs being poked far up the nose of the population to the base of the brain? A nasal swab punctured one woman's brain and caused it to leak fluid. Most of these procedures are being done by people with little training or medical knowledge. Dr Lorraine Day, former orthopaedic trauma surgeon and Chief of Orthopaedic Surgery at San Francisco General Hospital, says the tests are really a *'vaccine'*. Cows have long been vaccinated this way. She points out that masks have to cover the nose and the mouth where it is claimed the 'virus' exists in saliva. Why then don't they take saliva from the mouth as they do with a DNA test instead of pushing a long swab up the nose towards the brain? The ethmoid bone separates the nasal cavity from the brain and within that bone is the cribriform plate. Dr Day says that when the swab is pushed up against this plate and twisted the procedure is 'depositing things back there'. She claims that among these 'things' are nanoparticles that can enter the brain. Researchers have noted that a team at the Gates-funded Johns Hopkins have designed tiny, star-shaped micro-devices that can latch onto intestinal mucosa and release drugs into the body. Mucosa is the thin skin that covers the inside surface of parts of the body such as *the nose* and mouth and produces mucus to protect them. The Johns Hopkins micro-devices are called 'theragrippers' and were 'inspired' by a parasitic worm that digs its sharp teeth into a host's intestines. Nasal swabs are also coated in the sterilisation agent ethylene oxide. The US National Cancer Institute posts this explanation on its website:

> At room temperature, ethylene oxide is a flammable colorless gas with a sweet odor. It is used primarily to produce other chemicals, including antifreeze. In smaller amounts, ethylene oxide is used as a pesticide and a sterilizing agent. The ability of ethylene oxide to damage DNA makes it an effective sterilizing agent but also accounts for its cancer-causing activity.

The Institute mentions lymphoma and leukaemia as cancers most frequently reported to be associated with occupational exposure to ethylene oxide along with stomach and breast cancers. How does anyone think this is going to work out with the constant testing

regime being inflicted on adults and children at home and at school that will accumulate in the body anything that's on the swab?

Doctors know best

It is vital for people to realise that 'hero' doctors 'know' only what the Big Pharma-dominated medical authorities tell them to 'know' and if they refuse to 'know' what they are told to 'know' they are out the door. They are mostly not physicians or healers, but repeaters of the official narrative – or else. I have seen alleged professional doctors on British television make shocking statements that we are supposed to take seriously. One called 'Dr' Amir Khan, who is actually telling patients how to respond to illness, said that men could take the birth pill to 'help slow down the effects of Covid-19'. In March, 2021, another ridiculous 'Covid study' by an American doctor proposed injecting men with the female sex hormone progesterone as a 'Covid' treatment. British doctor Nighat Arif told the BBC that face coverings were now going to be part of ongoing normal. Yes, the vaccine protects you, she said (evidence?) … but the way to deal with viruses in the community was always going to come down to hand washing, face covering and keeping a physical distance. That's not what we were told before the 'vaccine' was circulating. Arif said she couldn't imagine ever again going on the underground or in a lift without a mask. I was just thanking my good luck that she was not my doctor when she said – in March, 2021 – that if 'we are *behaving* and we are doing all the right things' she thought we could 'have our nearest and dearest around us at home … around *Christmas* and N*ew Year!* Her patronising delivery was the usual school teacher talking to six-year-olds as she repeated every government talking point and probably believed them all. If we have learned anything from the 'Covid' experience surely it must be that humanity's perception of doctors needs a fundamental rethink. NHS 'doctor' Sara Kayat told her television audience that the 'Covid vaccine' would '100 percent prevent hospitalisation and death'. Not even Big Pharma claimed that. We have to stop taking 'experts' at their word without question when so many of them are

clueless and only repeating the party line on which their careers depend. That is not to say there are not brilliants doctors – there are and I have spoken to many of them since all this began – but you won't see them in the mainstream media or quoted by the psychopaths and yes-people in government.

Remember the name – Christian Drosten

German virologist Christian Drosten, Director of Charité Institute of Virology in Berlin, became a national star after the pandemic hoax began. He was feted on television and advised the German government on 'Covid' policy. Most importantly to the wider world Drosten led a group that produced the 'Covid' testing protocol for the PCR test. What a remarkable feat given the PCR cannot test for infectious disease and even more so when you think that Drosten said that his method of testing for SARS-CoV-2 was developed 'without having virus material available'. *He developed a test for a 'virus' that he didn't have and had never seen*. Let that sink in as you survey the global devastation that came from what he did. The whole catastrophe of Drosten's 'test' was based on the alleged genetic sequence published by Chinese scientists on the Internet. We will see in the next chapter that this alleged 'genetic sequence' has never been produced by China or anyone and cannot be when there *is no* SARS-CoV-2. Drosten, however, doesn't seem to let little details like that get in the way. He was the lead author with Victor Corman from the same Charité Hospital of the paper 'Detection of 2019 novel coronavirus (2019-nCoV) by real-time PCR' published in a magazine called *Eurosurveillance*. This became known as the Corman-Drosten paper. In November, 2020, with human society devastated by the effects of the Corman-Drosten test baloney, the protocol was publicly challenged by 22 international scientists and independent researchers from Europe, the United States, and Japan. Among them were senior molecular geneticists, biochemists, immunologists, and microbiologists. They produced a document headed 'External peer review of the RTPCR test to detect SARS-Cov-2 Reveals 10 Major Flaws At The Molecular and Methodological Level: Consequences

For False-Positive Results'. The flaws in the Corman-Drosten test included the following:

- The test is non-specific because of erroneous design
- Results are enormously variable
- The test is unable to discriminate between the whole 'virus' and viral fragments
- It doesn't have positive or negative controls
- The test lacks a standard operating procedure
- It is unsupported by proper peer view

The scientists said the PCR 'Covid' testing protocol was not founded on science and they demanded the Corman-Drosten paper be retracted by *Eurosurveillance*. They said all present and previous Covid deaths, cases, and 'infection rates' should be subject to a massive retroactive inquiry. Lockdowns and travel restrictions should be reviewed and relaxed and those diagnosed through PCR to have 'Covid-19' should not be forced to isolate. Dr Kevin Corbett, a health researcher and nurse educator with a long academic career producing a stream of peer-reviewed publications at many UK universities, made the same point about the PCR test debacle. He said of the scientists' conclusions: 'Every scientific rationale for the development of that test has been totally destroyed by this paper. It's like Hiroshima/Nagasaki to the Covid test.' He said that China hadn't given them an isolated 'virus' when Drosten developed the test. Instead they had developed the test from *a sequence in a gene bank*.' Put another way … *they made it up*! The scientists were supported in this contention by a Portuguese appeals court which ruled in November, 2020, that PCR tests are unreliable and it is unlawful to quarantine people based solely on a PCR test. The point about China not providing an isolated virus must be true when the 'virus' has never been isolated to this day and the consequences of that will become clear. Drosten and company produced this useless 'protocol' right on cue in January, 2020, just as the 'virus' was said to

be moving westward and it somehow managed to successfully pass a peer-review in 24 hours. In other words there was no peer-review for a test that would be used to decide who had 'Covid' and who didn't across the world. The Cult-created, Gates-controlled World Health Organization immediately recommended all its nearly 200 member countries to use the Drosten PCR protocol to detect 'cases' and 'deaths'. The sting was underway and it continues to this day.

So who is this Christian Drosten that produced the means through which death, destruction and economic catastrophe would be justified? His education background, including his doctoral thesis, would appear to be somewhat shrouded in mystery and his track record is dire as with another essential player in the 'Covid' hoax, the Gates-funded Professor Neil Ferguson at the Gates-funded Imperial College in London of whom more shortly. Drosten predicted in 2003 that the alleged original SARS 'virus' (SARS-1') was an epidemic that could have serious effects on economies and an effective vaccine would take at least two years to produce. Drosten's answer to every alleged 'outbreak' is a vaccine which you won't be shocked to know. What followed were just 774 official deaths worldwide and none in Germany where there were only nine cases. That is even if you believe there ever was a SARS 'virus' when the evidence is zilch and I will expand on this in the next chapter. Drosten claims to be co-discoverer of 'SARS-1' and developed a test for it in 2003. He was screaming warnings about 'swine flu' in 2009 and how it was a widespread infection far more severe than any dangers from a vaccine could be and people should get vaccinated. It would be helpful for Drosten's vocal chords if he simply recorded the words 'the virus is deadly and you need to get vaccinated' and copies could be handed out whenever the latest made-up threat comes along. Drosten's swine flu epidemic never happened, but Big Pharma didn't mind with governments spending hundreds of millions on vaccines that hardly anyone bothered to use and many who did wished they hadn't. A study in 2010 revealed that the risk of dying from swine flu, or H1N1, was no higher than that of the annual seasonal flu which is what at least most of 'it' really was as in

the case of 'Covid-19'. A media investigation into Drosten asked how with such a record of inaccuracy he could be *the* government adviser on these issues. The answer to that question is the same with Drosten, Ferguson and Fauci – they keep on giving the authorities the 'conclusions' and 'advice' they want to hear. Drosten certainly produced the goods for them in January, 2020, with his PCR protocol garbage and provided the foundation of what German internal medicine specialist Dr Claus Köhnlein, co-author of *Virus Mania*, called the 'test pandemic'. The 22 scientists in the *Eurosurveillance* challenge called out conflicts of interest within the Drosten 'protocol' group and with good reason. Olfert Landt, a regular co-author of Drosten 'studies', owns the biotech company TIB Molbiol Syntheselabor GmbH in Berlin which manufactures and sells the tests that Drosten and his mates come up with. They have done this with SARS, Enterotoxigenic E. coli (ETEC), MERS, Zika 'virus', yellow fever, and now 'Covid'. Landt told the *Berliner Zeitung* newspaper:

> The testing, design and development came from the Charité [Drosten and Corman]. We simply implemented it immediately in the form of a kit. And if we don't have the virus, which originally only existed in Wuhan, we can make a synthetic gene to simulate the genome of the virus. That's what we did very quickly.

This is more confirmation that the Drosten test was designed without access to the 'virus' and only a synthetic simulation which is what SARS-CoV-2 really is – a computer-generated synthetic fiction. It's quite an enterprise they have going here. A Drosten team decides what the test for something should be and Landt's biotech company flogs it to governments and medical systems across the world. His company must have made an absolute fortune since the 'Covid' hoax began. Dr Reiner Fuellmich, a prominent German consumer protection trial lawyer in Germany and California, is on Drosten's case and that of Tedros at the World Health Organization for crimes against humanity with a class-action lawsuit being prepared in the United States and other legal action in Germany.

Why China?

Scamming the world with a 'virus' that doesn't exist would seem impossible on the face of it, but not if you have control of the relatively few people that make policy decisions and the great majority of the global media. Remember it's not about changing 'real' reality it's about controlling *perception* of reality. You don't have to make something happen you only have make people *believe* that it's happening. Renegade Minds understand this and are therefore much harder to swindle. 'Covid-19' is not a 'real' 'virus'. It's a mind virus, like a computer virus, which has infected the minds, not the bodies, of billions. It all started, publically at least, in China and that alone is of central significance. The Cult was behind the revolution led by its asset Mao Zedong, or Chairman Mao, which established the People's Republic of China on October 1st, 1949. It should have been called The Cult's Republic of China, but the name had to reflect the recurring illusion that vicious dictatorships are run by and for the people (see all the 'Democratic Republics' controlled by tyrants). In the same way we have the 'Biden' Democratic Republic of America officially ruled by a puppet tyrant (at least temporarily) on behalf of Cult tyrants. The creation of Mao's merciless communist/fascist dictatorship was part of a frenzy of activity by the Cult at the conclusion of World War Two which, like the First World War, it had instigated through its assets in Germany, Britain, France, the United States and elsewhere. Israel was formed in 1948; the Soviet Union expanded its 'Iron Curtain' control, influence and military power with the Warsaw Pact communist alliance in 1955; the United Nations was formed in 1945 as a Cult precursor to world government; and a long list of world bodies would be established including the World Health Organization (1948), World Trade Organization (1948 under another name until 1995), International Monetary Fund (1945) and World Bank (1944). Human society was redrawn and hugely centralised in the global Problem-Reaction-Solution that was World War Two. All these changes were significant. Israel would become the headquarters of the Sabbatians

and the revolution in China would prepare the ground and control system for the events of 2019/2020.

Renegade Minds know there are no borders except for public consumption. The Cult is a seamless, borderless global entity and to understand the game we need to put aside labels like borders, nations, countries, communism, fascism and democracy. These delude the population into believing that countries are ruled within their borders by a government of whatever shade when these are mere agencies of a global power. America's illusion of democracy and China's communism/fascism are subsidiaries – vehicles – for the same agenda. We may hear about conflict and competition between America and China and on the lower levels that will be true; but at the Cult level they are branches of the same company in the way of the McDonald's example I gave earlier. I have tracked in the books over the years support by US governments of both parties for Chinese Communist Party infiltration of American society through allowing the sale of land, even military facilities, and the acquisition of American business and university influence. All this is underpinned by the infamous stealing of intellectual property and technological know-how. Cult-owned Silicon Valley corporations waive their fraudulent 'morality' to do business with human-rights-free China; Cult-controlled Disney has become China's PR department; and China in effect owns 'American' sports such as basketball which depends for much of its income on Chinese audiences. As a result any sports player, coach or official speaking out against China's horrific human rights record is immediately condemned or fired by the China-worshipping National Basketball Association. One of the first acts of China-controlled Biden was to issue an executive order telling federal agencies to stop making references to the 'virus' by the 'geographic location of its origin'. Long-time Congressman Jerry Nadler warned that criticising China, America's biggest rival, leads to hate crimes against Asian people in the United States. So shut up you bigot. China is fast closing in on Israel as a country that must not be criticised which is apt, really, given that Sabbatians control them both. The two countries have

developed close economic, military, technological and strategic ties which include involvement in China's 'Silk Road' transport and economic initiative to connect China with Europe. Israel was the first country in the Middle East to recognise the establishment of Mao's tyranny in 1950 months after it was established.

Project Wuhan – the 'Covid' Psyop

I emphasise again that the Cult plays the long game and what is happening to the world today is the result of centuries of calculated manipulation following a script to take control step-by-step of every aspect of human society. I will discuss later the common force behind all this that has spanned those centuries and thousands of years if the truth be told. Instigating the Mao revolution in China in 1949 with a 2020 'pandemic' in mind is not only how they work – the 71 years between them is really quite short by the Cult's standards of manipulation preparation. The reason for the Cult's Chinese revolution was to create a fiercely-controlled environment within which an extreme structure for human control could be incubated to eventually be unleashed across the world. We have seen this happen since the 'pandemic' emerged from China with the Chinese control-structure founded on AI technology and tyrannical enforcement sweep across the West. Until the moment when the Cult went for broke in the West and put its fascism on public display Western governments had to pay some lip-service to freedom and democracy to not alert too many people to the tyranny-in-the-making. Freedoms were more subtly eroded and power centralised with covert government structures put in place waiting for the arrival of 2020 when that smokescreen of 'freedom' could be dispensed with. The West was not able to move towards tyranny before 2020 anything like as fast as China which was created as a tyranny and had no limits on how fast it could construct the Cult's blueprint for global control. When the time came to impose that structure on the world it was the same Cult-owned Chinese communist/fascist government that provided the excuse – the 'Covid pandemic'. It was absolutely crucial to the Cult plan for the Chinese response to the 'pandemic' –

draconian lockdowns of the entire population – to become the blueprint that Western countries would follow to destroy the livelihoods and freedom of their people. This is why the Cult-owned, Gates-owned, WHO Director-General Tedros said early on:

The Chinese government is to be congratulated for the extraordinary measures it has taken to contain the outbreak. China is actually setting a new standard for outbreak response and it is not an exaggeration.

Forbes magazine said of China: '… those measures protected untold millions from getting the disease'. The Rockefeller Foundation 'epidemic scenario' document in 2010 said 'prophetically':

However, a few countries did fare better – China in particular. The Chinese government's quick imposition and enforcement of mandatory quarantine for all citizens, as well as its instant and near-hermetic sealing off of all borders, saved millions of lives, stopping the spread of the virus far earlier than in other countries and enabling a swifter post-pandemic recovery.

Once again – *spooky*.

The first official story was the 'bat theory' or rather the bat diversion. The source of the 'virus outbreak' we were told was a ''wet market' in Wuhan where bats and other animals are bought and eaten in horrifically unhygienic conditions. Then another story emerged through the alternative media that the 'virus' had been released on purpose or by accident from a BSL-4 (biosafety level 4) laboratory in Wuhan not far from the wet market. The lab was reported to create and work with lethal concoctions and bioweapons. Biosafety level 4 is the highest in the World Health Organization system of safety and containment. Renegade Minds are aware of what I call designer manipulation. The ideal for the Cult is for people to buy its prime narrative which in the opening salvoes of the 'pandemic' was the wet market story. It knows, however, that there is now a considerable worldwide alternative media of researchers sceptical of anything governments say and they are often given a version of events in a form they can perceive as credible while misdirecting them from the real truth. In this case let them

think that the conspiracy involved is a 'bioweapon virus' released from the Wuhan lab to keep them from the real conspiracy – *there is no 'virus'*. The WHO's current position on the source of the outbreak at the time of writing appears to be: 'We haven't got a clue, mate.' This is a good position to maintain mystery and bewilderment. The inner circle will know where the 'virus' came from – *nowhere*. The bottom line was to ensure the public believed there *was* a 'virus' and it didn't much matter if they thought it was natural or had been released from a lab. The belief that there was a 'deadly virus' was all that was needed to trigger global panic and fear. The population was terrified into handing their power to authority and doing what they were told. They had to or they were 'all gonna die'.

In March, 2020, information began to come my way from real doctors and scientists and my own additional research which had my intuition screaming: 'Yes, that's it! *There is no virus*.' The 'bioweapon' was not the 'virus'; it was the *'vaccine'* already being talked about that would be the bioweapon. My conclusion was further enhanced by happenings in Wuhan. The 'virus' was said to be sweeping the city and news footage circulated of people collapsing in the street (which they've never done in the West with the same 'virus'). The Chinese government was building 'new hospitals' in a matter of ten days to 'cope with demand' such was the virulent nature of the 'virus'. Yet in what seemed like no time the 'new hospitals' closed – even if they even opened – and China declared itself 'virus-free'. It was back to business as usual. This was more propaganda to promote the Chinese draconian lockdowns in the West as the way to 'beat the virus'. Trouble was that we subsequently had lockdown after lockdown, but never business as usual. As the people of the West and most of the rest of the world were caught in an ever-worsening spiral of lockdown, social distancing, masks, isolated old people, families forced apart, and livelihood destruction, it was party-time in Wuhan. Pictures emerged of thousands of people enjoying pool parties and concerts. It made no sense until you realised there never was a 'virus' and the

whole thing was a Cult set-up to transform human society out of one its major global strongholds – China.

How is it possible to deceive virtually the entire world population into believing there is a deadly virus when there is not even a 'virus' let alone a deadly one? It's nothing like as difficult as you would think and that's clearly true because it happened.

Postscript: See end of book Postscript for more on the 'Wuhan lab virus release' story which the authorities and media were pushing heavily in the summer of 2021 to divert attention from the truth that the 'Covid virus' is pure invention.

CHAPTER FIVE

There *is no* 'virus'

You can fool some of the people all of the time, and all of the people some of the time, but you cannot fool all of the people all of the time
Abraham Lincoln

The greatest form of mind control is repetition. The more you repeat the same mantra of alleged 'facts' the more will accept them to be true. It becomes an 'everyone knows that, mate'. If you can also censor any other version or alternative to your alleged 'facts' you are pretty much home and cooking.

By the start of 2020 the Cult owned the global mainstream media almost in its entirety to spew out its 'Covid' propaganda and ignore or discredit any other information and view. Cult-owned social media platforms in Cult-owned Silicon Valley were poised and ready to unleash a campaign of ferocious censorship to obliterate all but the official narrative. To complete the circle many demands for censorship by Silicon Valley were led by the mainstream media as 'journalists' became full-out enforcers for the Cult both as propagandists and censors. Part of this has been the influx of young people straight out of university who have become 'journalists' in significant positions. They have no experience and a headful of programmed perceptions from their years at school and university at a time when today's young are the most perceptually-targeted generations in known human history given the insidious impact of technology. They enter the media perceptually prepared and ready to repeat the narratives of the system that programmed them to

repeat its narratives. The BBC has a truly pathetic 'specialist disinformation reporter' called Marianna Spring who fits this bill perfectly. She is clueless about the world, how it works and what is really going on. Her role is to discredit anyone doing the job that a proper journalist would do and system-serving hacks like Spring wouldn't dare to do or even see the need to do. They are too busy licking the arse of authority which can never be wrong and, in the case of the BBC propaganda programme, *Panorama*, contacting payments systems such as PayPal to have a donations page taken down for a film company making documentaries questioning vaccines. Even the BBC soap opera *EastEnders* included a disgracefully biased scene in which an inarticulate white working class woman was made to look foolish for questioning the 'vaccine' while a well-spoken black man and Asian woman promoted the government narrative. It ticked every BBC box and the fact that the black and minority community was resisting the 'vaccine' had nothing to do with the way the scene was written. The BBC has become a disgusting tyrannical propaganda and censorship operation that should be defunded and disbanded and a free media take its place with a brief to stop censorship instead of demanding it. A BBC 'interview' with Gates goes something like: 'Mr Gates, sir, if I can call you sir, would you like to tell our audience why you are such a great man, a wonderful humanitarian philanthropist, and why you should absolutely be allowed as a software salesman to decide health policy for approaching eight billion people? Thank you, sir, please sir.' Propaganda programming has been incessant and merciless and when all you hear is the same story from the media, repeated by those around you who have only heard the same story, is it any wonder that people on a grand scale believe absolute mendacious garbage to be true? You are about to see, too, why this level of information control is necessary when the official 'Covid' narrative is so nonsensical and unsupportable by the evidence.

Structure of Deceit

The pyramid structure through which the 'Covid' hoax has been manifested is very simple and has to be to work. As few people as possible have to be involved with full knowledge of what they are doing – and why – or the real story would get out. At the top of the pyramid are the inner core of the Cult which controls Bill Gates who, in turn, controls the World Health Organization through his pivotal funding and his puppet Director-General mouthpiece, Tedros. Before he was appointed Tedros was chair of the Gates-founded Global Fund to 'fight against AIDS, tuberculosis and malaria', a board member of the Gates-funded 'vaccine alliance' GAVI, and on the board of another Gates-funded organisation. Gates owns him and picked him for a specific reason – Tedros is a crook and worse. 'Dr' Tedros (he's not a medical doctor, the first WHO chief not to be) was a member of the tyrannical Marxist government of Ethiopia for decades with all its human rights abuses. He has faced allegations of corruption and misappropriation of funds and was exposed three times for covering up cholera epidemics while Ethiopia's health minister. Tedros appointed the mass-murdering genocidal Zimbabwe dictator Robert Mugabe as a WHO goodwill ambassador for public health which, as with Tedros, is like appointing a psychopath to run a peace and love campaign. The move was so ridiculous that he had to drop Mugabe in the face of widespread condemnation. American economist David Steinman, a Nobel peace prize nominee, lodged a complaint with the International Criminal Court in The Hague over alleged genocide by Tedros when he was Ethiopia's foreign minister. Steinman says Tedros was a 'crucial decision maker' who directed the actions of Ethiopia's security forces from 2013 to 2015 and one of three officials in charge when those security services embarked on the 'killing' and 'torturing' of Ethiopians. You can see where Tedros is coming from and it's sobering to think that he has been the vehicle for Gates and the Cult to direct the global response to 'Covid'. Think about that. A psychopathic Cult dictates to psychopath Gates who dictates to psychopath Tedros who dictates how countries of the world must respond to a 'Covid virus' never scientifically shown to exist. At the same time psychopathic Cult-owned Silicon Valley information

giants like Google, YouTube, Facebook and Twitter announced very early on that they would give the Cult/Gates/Tedros/WHO version of the narrative free advertising and censor those who challenged their intelligence-insulting, mendacious story.

The next layer in the global 'medical' structure below the Cult, Gates and Tedros are the chief medical officers and science 'advisers' in each of the WHO member countries which means virtually all of them. Medical officers and arbiters of science (they're not) then take the WHO policy and recommended responses and impose them on their country's population while the political 'leaders' say they are deciding policy (they're clearly not) by 'following the science' on the advice of the 'experts' – the same medical officers and science 'advisers' (dictators). In this way with the rarest of exceptions the entire world followed the same policy of lockdown, people distancing, masks and 'vaccines' dictated by the psychopathic Cult, psychopathic Gates and psychopathic Tedros who we are supposed to believe give a damn about the health of the world population they are seeking to enslave. That, amazingly, is all there is to it in terms of crucial decision-making. Medical staff in each country then follow like sheep the dictates of the shepherds at the top of the national medical hierarchies – chief medical officers and science 'advisers' who themselves follow like sheep the shepherds of the World Health Organization and the Cult. Shepherds at the national level often have major funding and other connections to Gates and his Bill and Melinda Gates Foundation which carefully hands out money like confetti at a wedding to control the entire global medical system from the WHO down.

Follow the money

Christopher Whitty, Chief Medical Adviser to the UK Government at the centre of 'virus' policy, a senior adviser to the government's Scientific Advisory Group for Emergencies (SAGE), and Executive Board member of the World Health Organization, was gifted a grant of $40 million by the Bill and Melinda Gates Foundation for malaria research in Africa. The BBC described the unelected Whitty as 'the

official who will probably have the greatest impact on our everyday lives of any individual policymaker in modern times' and so it turned out. What Gates and Tedros have said Whitty has done like his equivalents around the world. Patrick Vallance, co-chair of SAGE and the government's Chief Scientific Adviser, is a former executive of Big Pharma giant GlaxoSmithKline with its fundamental financial and business connections to Bill Gates. In September, 2020, it was revealed that Vallance owned a deferred bonus of shares in GlaxoSmithKline worth £600,000 while the company was 'developing' a 'Covid vaccine'. Move along now – nothing to see here – what could possibly be wrong with that? Imperial College in London, a major player in 'Covid' policy in Britain and elsewhere with its 'Covid-19' Response Team, is funded by Gates and has big connections to China while the now infamous Professor Neil Ferguson, the useless 'computer modeller' at Imperial College is also funded by Gates. Ferguson delivered the dramatically inaccurate excuse for the first lockdowns (much more in the next chapter). The Institute for Health Metrics and Evaluation (IHME) in the United States, another source of outrageously false 'Covid' computer models to justify lockdowns, is bankrolled by Gates who is a vehement promotor of lockdowns. America's version of Whitty and Vallance, the again now infamous Anthony Fauci, has connections to 'Covid vaccine' maker Moderna as does Bill Gates through funding from the Bill and Melinda Gates Foundation. Fauci is director of the National Institute of Allergy and Infectious Diseases (NIAID), a major recipient of Gates money, and they are very close. Deborah Birx who was appointed White House Coronavirus Response Coordinator in February, 2020, is yet another with ties to Gates. Everywhere you look at the different elements around the world behind the coordination and decision making of the 'Covid' hoax there is Bill Gates and his money. They include the World Health Organization; Centers for Disease Control (CDC) in the United States; National Institutes of Health (NIH) of Anthony Fauci; Imperial College and Neil Ferguson; the London School of Hygiene where Chris Whitty worked; Regulatory agencies like the UK Medicines & Healthcare products Regulatory Agency (MHRA)

which gave emergency approval for 'Covid vaccines'; Wellcome Trust; GAVI, the Vaccine Alliance; the Coalition for Epidemic Preparedness Innovations (CEPI); Johns Hopkins University which has compiled the false 'Covid' figures; and the World Economic Forum. A Nationalfile.com article said:

> Gates has a lot of pull in the medical world, he has a multi-million dollar relationship with Dr. Fauci, and Fauci originally took the Gates line supporting vaccines and casting doubt on [the drug hydroxychloroquine]. Coronavirus response team member Dr. Deborah Birx, appointed by former president Obama to serve as United States Global AIDS Coordinator, also sits on the board of a group that has received billions from Gates' foundation, and Birx reportedly used a disputed Bill Gates-funded model for the White House's Coronavirus effort. Gates is a big proponent for a population lockdown scenario for the Coronavirus outbreak.

Another funder of Moderna is the Defense Advanced Research Projects Agency (DARPA), the technology-development arm of the Pentagon and one of the most sinister organisations on earth. DARPA had a major role with the CIA covert technology-funding operation In-Q-Tel in the development of Google and social media which is now at the centre of global censorship. Fauci and Gates are extremely close and openly admit to talking regularly about 'Covid' policy, but then why wouldn't Gates have a seat at every national 'Covid' table after his Foundation committed $1.75 billion to the 'fight against Covid-19'. When passed through our Orwellian Translation Unit this means that he has bought and paid for the Cult-driven 'Covid' response worldwide. Research the major 'Covid' response personnel in your own country and you will find the same Gates funding and other connections again and again. Medical and science chiefs following World Health Organization 'policy' sit atop a medical hierarchy in their country of administrators, doctors and nursing staff. These 'subordinates' are told they must work and behave in accordance with the policy delivered from the 'top' of the national 'health' pyramid which is largely the policy delivered by the WHO which is the policy delivered by Gates and the Cult. The whole 'Covid' narrative has been imposed on medical staff by a climate of fear although great numbers don't even need that to comply. They do so through breathtaking levels of ignorance and

include doctors who go through life simply repeating what Big Pharma and their hierarchical masters tell them to say and believe. No wonder Big Pharma 'medicine' is one of the biggest killers on Planet Earth.

The same top-down system of intimidation operates with regard to the Cult Big Pharma cartel which also dictates policy through national and global medical systems in this way. The Cult and Big Pharma agendas are the same because the former controls and owns the latter. 'Health' administrators, doctors, and nursing staff are told to support and parrot the dictated policy or they will face consequences which can include being fired. How sad it's been to see medical staff meekly repeating and imposing Cult policy without question and most of those who can see through the deceit are only willing to speak anonymously off the record. They know what will happen if their identity is known. This has left the courageous few to expose the lies about the 'virus', face masks, overwhelmed hospitals that aren't, and the dangers of the 'vaccine' that isn't a vaccine. When these medical professionals and scientists, some renowned in their field, have taken to the Internet to expose the truth their articles, comments and videos have been deleted by Cult-owned Facebook, Twitter and YouTube. What a real head-shaker to see YouTube videos with leading world scientists and highly qualified medical specialists with an added link underneath to the notorious Cult propaganda website *Wikipedia* to find the 'facts' about the same subject.

HIV – the 'Covid' trial-run

I'll give you an example of the consequences for health and truth that come from censorship and unquestioning belief in official narratives. The story was told by PCR inventor Kary Mullis in his book *Dancing Naked in the Mind Field*. He said that in 1984 he accepted as just another scientific fact that Luc Montagnier of France's Pasteur Institute and Robert Gallo of America's National Institutes of Health had independently discovered that a 'retrovirus' dubbed HIV (human immunodeficiency virus) caused AIDS. They

were, after all, Mullis writes, specialists in retroviruses. This is how the medical and science pyramids work. Something is announced or *assumed* and then becomes an everybody-knows-that purely through repetition of the assumption as if it is fact. Complete crap becomes accepted truth with no supporting evidence and only repetition of the crap. This is how a 'virus' that doesn't exist became the 'virus' that changed the world. The HIV-AIDS fairy story became a multi-billion pound industry and the media poured out propaganda terrifying the world about the deadly HIV 'virus' that caused the lethal AIDS. By then Mullis was working at a lab in Santa Monica, California, to detect retroviruses with his PCR test in blood donations received by the Red Cross. In doing so he asked a virologist where he could find a reference for HIV being the cause of AIDS. 'You don't need a reference,' the virologist said … *'Everybody knows it.'* Mullis said he wanted to quote a reference in the report he was doing and he said he felt a little funny about not knowing the source of such an important discovery when everyone else seemed to. The virologist suggested he cite a report by the Centers for Disease Control and Prevention (CDC) on morbidity and mortality. Mullis read the report, but it only said that an organism had been identified and did not say how. The report did not identify the original scientific work. Physicians, however, *assumed* (key recurring theme) that if the CDC was convinced that HIV caused AIDS then proof must exist. Mullis continues:

I did computer searches. Neither Montagnier, Gallo, nor anyone else had published papers describing experiments which led to the conclusion that HIV probably caused AIDS. I read the papers in Science for which they had become well known as AIDS doctors, but all they had said there was that they had found evidence of a past infection by something which was probably HIV in some AIDS patients.

They found antibodies. Antibodies to viruses had always been considered evidence of past disease, not present disease. Antibodies signaled that the virus had been defeated. The patient had saved himself. There was no indication in these papers that this virus caused a disease. They didn't show that everybody with the antibodies had the disease. In fact they found some healthy people with antibodies.

Mullis asked why their work had been published if Montagnier and Gallo hadn't really found this evidence, and why had they been fighting so hard to get credit for the discovery? He says he was hesitant to write 'HIV is the probable cause of AIDS' until he found published evidence to support that. 'Tens of thousands of scientists and researchers were spending billions of dollars a year doing research based on this idea,' Mullis writes. 'The reason had to be there somewhere; otherwise these people would not have allowed their research to settle into one narrow channel of investigation.' He said he lectured about PCR at numerous meetings where people were always talking about HIV and he asked them how they knew that HIV was the cause of AIDS:

> Everyone said something. Everyone had the answer at home, in the office, in some drawer. They all knew, and they would send me the papers as soon as they got back. But I never got any papers. Nobody ever sent me the news about how AIDS was caused by HIV.

Eventually Mullis was able to ask Montagnier himself about the reference proof when he lectured in San Diego at the grand opening of the University of California AIDS Research Center. Mullis says this was the last time he would ask his question without showing anger. Montagnier said he should reference the CDC report. 'I read it', Mullis said, and it didn't answer the question. 'If Montagnier didn't know the answer who the hell did?' Then one night Mullis was driving when an interview came on National Public Radio with Peter Duesberg, a prominent virologist at Berkeley and a California Scientist of the Year. Mullis says he finally understood why he could not find references that connected HIV to AIDS – *there weren't any!* No one had ever proved that HIV causes AIDS even though it had spawned a multi-billion pound global industry and the media was repeating this as fact every day in their articles and broadcasts terrifying the shit out of people about AIDS and giving the impression that a positive test for HIV (see 'Covid') was a death sentence. Duesberg was a threat to the AIDS gravy train and the agenda that underpinned it. He was therefore abused and castigated after he told the Proceedings of the National Academy of Sciences

there was no good evidence implicating the new 'virus'. Editors rejected his manuscripts and his research funds were deleted. Mullis points out that the CDC has defined AIDS as one of more than 30 diseases *if accompanied* by a positive result on a test that detects antibodies to HIV; but those same diseases are not defined as AIDS cases when antibodies are not detected:

> If an HIV-positive woman develops uterine cancer, for example, she is considered to have AIDS. If she is not HIV positive, she simply has uterine cancer. An HIV-positive man with tuberculosis has AIDS; if he tests negative he simply has tuberculosis. If he lives in Kenya or Colombia, where the test for HIV antibodies is too expensive, he is simply presumed to have the antibodies and therefore AIDS, and therefore he can be treated in the World Health Organization's clinic. It's the only medical help available in some places. And it's free, because the countries that support WHO are worried about AIDS.

Mullis accuses the CDC of continually adding new diseases (see ever more 'Covid symptoms') to the grand AIDS definition and of virtually doctoring the books to make it appear as if the disease continued to spread. He cites how in 1993 the CDC enormously broadened its AIDS definition and county health authorities were delighted because they received $2,500 per year from the Federal government for every reported AIDS case. Ladies and gentlemen, I have just described, via Kary Mullis, the 'Covid pandemic' of 2020 and beyond. Every element is the same and it's been pulled off in the same way by the same networks.

The 'Covid virus' exists? Okay – prove it. Er … still waiting

What Kary Mullis described with regard to 'HIV' has been repeated with 'Covid'. A claim is made that a new, or 'novel', infection has been found and the entire medical system of the world repeats that as fact exactly as they did with HIV and AIDS. No one in the mainstream asks rather relevant questions such as 'How do you know?' and 'Where is your proof?' The SARS-Cov-2 'virus' and the 'Covid-19 disease' became an overnight 'everybody-knows-that'. The origin could be debated and mulled over, but what you could not suggest was that 'SARS-Cov-2' didn't exist. That would be

ridiculous. 'Everybody knows' the 'virus' exists. Well, I didn't for one along with American proper doctors like Andrew Kaufman and Tom Cowan and long-time American proper journalist Jon Rappaport. We dared to pursue the obvious and simple question: 'Where's the evidence?' The overwhelming majority in medicine, journalism and the general public did not think to ask that. After all, *everyone knew* there was a new 'virus'. Everyone was saying so and I heard it on the BBC. Some would eventually argue that the 'deadly virus' was nothing like as deadly as claimed, but few would venture into the realms of its very existence. Had they done so they would have found that the evidence for that claim had gone AWOL as with HIV causes AIDS. In fact, not even that. For something to go AWOL it has to exist in the first place and scientific proof for a 'SARS-Cov-2' can be filed under nothing, nowhere and zilch.

Dr Andrew Kaufman is a board-certified forensic psychiatrist in New York State, a Doctor of Medicine and former Assistant Professor and Medical Director of Psychiatry at SUNY Upstate Medical University, and Medical Instructor of Hematology and Oncology at the Medical School of South Carolina. He also studied biology at the Massachusetts Institute of Technology (MIT) and trained in Psychiatry at Duke University. Kaufman is retired from allopathic medicine, but remains a consultant and educator on natural healing, I saw a video of his very early on in the 'Covid' hoax in which he questioned claims about the 'virus' in the absence of any supporting evidence and with plenty pointing the other way. I did everything I could to circulate his work which I felt was asking the pivotal questions that needed an answer. I can recommend an excellent pull-together interview he did with the website The Last Vagabond entitled *Dr Andrew Kaufman: Virus Isolation, Terrain Theory and Covid-19* and his website is andrewkaufmanmd.com. Kaufman is not only a forensic psychiatrist; he is forensic in all that he does. He always reads original scientific papers, experiments and studies instead of second-third-fourth-hand reports about the 'virus' in the media which are repeating the repeated repetition of the narrative. When he did so with the original Chinese 'virus' papers Kaufman

realised that there was no evidence of a 'SARS-Cov-2'. They had never – from the start – shown it to exist and every repeat of this claim worldwide was based on the accepted existence of proof that was nowhere to be found – see Kary Mullis and HIV. Here we go again.

Let's postulate

Kaufman discovered that the Chinese authorities immediately concluded that the cause of an illness that broke out among about 200 initial patients in Wuhan was a 'new virus' when there were no grounds to make that conclusion. The alleged 'virus' was not isolated from other genetic material in their samples and then shown through a system known as Koch's postulates to be the causative agent of the illness. The world was told that the SARS-Cov-2 'virus' caused a disease they called 'Covid-19' which had 'flu-like' symptoms and could lead to respiratory problems and pneumonia. If it wasn't so tragic it would almost be funny. *'Flu-like' symptoms'? Pneumonia? Respiratory disease?* What in *CHINA* and particularly in *Wuhan*, one of the most polluted cities in the world with a resulting epidemic of respiratory disease?? Three hundred thousand people get pneumonia in China every year and there are nearly a billion cases worldwide of 'flu-like symptoms'. These have a whole range of causes – including pollution in Wuhan – but no other possibility was credibly considered in late 2019 when the world was told there was a new and deadly 'virus'. The global prevalence of pneumonia and 'flu-like systems' gave the Cult networks unlimited potential to re-diagnose these other causes as the mythical 'Covid-19' and that is what they did from the very start. Kaufman revealed how Chinese medical and science authorities (all subordinates to the Cult-owned communist government) took genetic material from the lungs of only a few of the first patients. The material contained their own cells, bacteria, fungi and other microorganisms living in their bodies. The only way you could prove the existence of the 'virus' and its responsibility for the alleged 'Covid-19' was to isolate the virus from all the other material – a process also known as 'purification' – and

then follow the postulates sequence developed in the late 19th century by German physician and bacteriologist Robert Koch which became the 'gold standard' for connecting an alleged causation agent to a disease:

1. The microorganism (bacteria, fungus, virus, etc.) must be present in every case of the disease and all patients must have the same symptoms. It must also *not be present in healthy individuals*.

2. The microorganism must be isolated from the host with the disease. If the microorganism is a bacteria or fungus it must be grown in a pure culture. If it is a virus, it must be purified (i.e. containing no other material except the virus particles) from a clinical sample.

3. The specific disease, with all of its characteristics, must be reproduced when the infectious agent (the purified virus or a pure culture of bacteria or fungi) is inoculated into a healthy, susceptible host.

4. The microorganism must be recoverable from the experimentally infected host as in step 2.

Not one of these criteria has been met in the case of 'SARS-Cov-2' and 'Covid-19'. Not ONE. *EVER*. Robert Koch refers to bacteria and not viruses. What are called 'viral particles' are so minute (hence masks are useless by any definition) that they could only be seen after the invention of the electron microscope in the 1930s and can still only be observed through that means. American bacteriologist and virologist Thomas Milton Rivers, the so-called 'Father of Modern Virology' who was very significantly director of the Rockefeller Institute for Medical Research in the 1930s, developed a less stringent version of Koch's postulates to identify 'virus' causation known as 'Rivers criteria'. 'Covid' did not pass that process either. Some even doubt whether any 'virus' can be isolated from other particles containing genetic material in the Koch method. Freedom of Information requests in many countries asking for scientific proof that the 'Covid virus' has been purified and isolated and shown to exist have all come back with a 'we don't have that' and when this happened with a request to the UK Department of Health they added this comment:

However, outside of the scope of the [Freedom of Information Act] and on a discretionary basis, the following information has been advised to us, which may be of interest. Most infectious diseases are caused by viruses, bacteria or fungi. Some bacteria or fungi have the capacity to grow on their own in isolation, for example in colonies on a petri dish. Viruses are different in that they are what we call 'obligate pathogens' – that is, they cannot survive or reproduce without infecting a host ...

… For some diseases, it is possible to establish causation between a microorganism and a disease by isolating the pathogen from a patient, growing it in pure culture and reintroducing it to a healthy organism. These are known as 'Koch's postulates' and were developed in 1882. However, as our understanding of disease and different disease-causing agents has advanced, these are no longer the method for determining causation [Andrew Kaufman asks why in that case are there two published articles falsely claiming to satisfy Koch's postulates].

It has long been known that viral diseases cannot be identified in this way as viruses cannot be grown in 'pure culture'. When a patient is tested for a viral illness, this is normally done by looking for the presence of antigens, or viral genetic code in a host with molecular biology techniques [Kaufman asks how you could know the origin of these chemicals without having a pure culture for comparison].

For the record 'antigens' are defined so:

Invading microorganisms have antigens on their surface that the human body can recognise as being foreign – meaning not belonging to it. When the body recognises a foreign antigen, lymphocytes (white blood cells) produce antibodies, which are complementary in shape to the antigen.

Notwithstanding that this is open to question in relation to 'SARS-Cov-2' the presence of 'antibodies' can have many causes and they are found in people that are perfectly well. Kary Mullis said: 'Antibodies … had always been considered evidence of past disease, not present disease.'

'Covid' really is a *computer* 'virus'

Where the UK Department of Health statement says 'viruses' are now 'diagnosed' through a 'viral genetic code in a host with molecular biology techniques', they mean … *the PCR test* which its inventor said cannot test for infectious disease. They have no credible method of connecting a 'virus' to a disease and we will see that there is no scientific proof that any 'virus' causes any disease or there is any such thing as a 'virus' in the way that it is described. Tenacious Canadian researcher Christine Massey and her team made

some 40 Freedom of Information requests to national public health agencies in different countries asking for proof that SARS-CoV-2 has been isolated and not one of them could supply that information. Massey said of her request in Canada: 'Freedom of Information reveals Public Health Agency of Canada has no record of 'SARS-COV-2' isolation performed by anyone, anywhere, ever.' If you accept the comment from the UK Department of Health it's because they can't isolate a 'virus'. Even so many 'science' papers claimed to have isolated the 'Covid virus' until they were questioned and had to admit they hadn't. A reply from the Robert Koch Institute in Germany was typical: 'I am not aware of a paper which purified isolated SARS-CoV-2.' So what the hell was Christian Drosten and his gang using to design the 'Covid' testing protocol that has produced all the illusory Covid' cases and 'Covid' deaths when the head of the Chinese version of the CDC admitted there was a problem right from the start in that the 'virus' had never been isolated/purified? Breathe deeply: What they are calling 'Covid' is actually created by a *computer program* i.e. *they made it up* – er, that's it. They took lung fluid, with many sources of genetic material, from one single person alleged to be infected with Covid-19 by a PCR test which they *claimed*, without clear evidence, contained a 'virus'. They used several computer programs to create a model of a theoretical virus genome sequence from more than fifty-six million small sequences of RNA, each of an unknown source, assembling them like a puzzle with no known solution. The computer filled in the gaps with sequences from bits in the gene bank to make it look like a bat SARS-like coronavirus! A wave of the magic wand and poof, an in silico (computer-generated) genome, a scientific fantasy, was created. UK health researcher Dr Kevin Corbett made the same point with this analogy:

> … It's like giving you a few bones and saying that's your fish. It could be any fish. Not even a skeleton. Here's a few fragments of bones. That's your fish … It's all from gene bank and the bits of the virus sequence that weren't there they made up.
>
> They synthetically created them to fill in the blanks. That's what genetics is; it's a code. So it's ABBBCCDDD and you're missing some what you think is EEE so you put it in. It's all

synthetic. You just manufacture the bits that are missing. This is the end result of the geneticization of virology. This is basically a computer virus.

Further confirmation came in an email exchange between British citizen journalist Frances Leader and the government's Medicines & Healthcare Products Regulatory Agency (the Gates-funded MHRA) which gave emergency permission for untested 'Covid vaccines' to be used. The agency admitted that the 'vaccine' is not based on an isolated 'virus', but comes from a *computer-generated model*. Frances Leader was naturally banned from Cult-owned fascist Twitter for making this exchange public. The process of creating computer-generated alleged 'viruses' is called 'in silico' or 'in silicon' – computer chips – and the term 'in silico' is believed to originate with biological experiments using only a computer in 1989. 'Vaccines' involved with 'Covid' are also produced 'in silico' or by computer not a natural process. If the original 'virus' is nothing more than a made-up computer model how can there be 'new variants' of something that never existed in the first place? They are not new 'variants'; they are new *computer models* only minutely different to the original program and designed to further terrify the population into having the 'vaccine' and submitting to fascism. You want a 'new variant'? Click, click, enter – there you go. Tell the medical profession that you have discovered a 'South African variant', 'UK variants' or a 'Brazilian variant' and in the usual HIV-causes-AIDS manner they will unquestioningly repeat it with no evidence whatsoever to support these claims. They will go on television and warn about the dangers of 'new variants' while doing nothing more than repeating what they have been told to be true and knowing that any deviation from that would be career suicide. Big-time insiders will know it's a hoax, but much of the medical community is clueless about the way they are being played and themselves play the public without even being aware they are doing so. What an interesting 'coincidence' that AstraZeneca and Oxford University were conducting 'Covid vaccine trials' in the three countries – the UK, South Africa and Brazil – where the first three 'variants' were claimed to have 'broken out'.

Here's your 'virus' – it's a unicorn

Dr Andrew Kaufman presented a brilliant analysis describing how the 'virus' was imagined into fake existence when he dissected an article published by *Nature* and written by 19 authors detailing *alleged* 'sequencing of a complete viral genome' of the 'new SARS-CoV-2 virus'. This computer-modelled *in silico* genome was used as a template for all subsequent genome sequencing experiments that resulted in the so-called variants which he said now number more than *6,000*. The fake genome was constructed from more than 56 million individual short strands of RNA. Those little pieces were assembled into longer pieces by finding areas of overlapping sequences. The computer programs created over two million possible combinations from which the authors simply chose the longest one. They then compared this to a 'bat virus' and the computer 'alignment' rearranged the sequence and filled in the gaps! They called this computer-generated abomination the 'complete genome'. Dr Tom Cowan, a fellow medical author and collaborator with Kaufman, said such computer-generation constitutes scientific fraud and he makes this superb analogy:

> Here is an equivalency: A group of researchers claim to have found a unicorn because they found a piece of a hoof, a hair from a tail, and a snippet of a horn. They then add that information into a computer and program it to re-create the unicorn, and they then claim this computer re-creation is the real unicorn. Of course, they had never actually seen a unicorn so could not possibly have examined its genetic makeup to compare their samples with the actual unicorn's hair, hooves and horn.
>
> The researchers claim they decided which is the real genome of SARS-CoV-2 by 'consensus', sort of like a vote. Again, different computer programs will come up with different versions of the imaginary 'unicorn', so they come together as a group and decide which is the real imaginary unicorn.

This is how the 'virus' that has transformed the world was brought into fraudulent 'existence'. Extraordinary, yes, but as the Nazis said the bigger the lie the more will believe it. Cowan, however, wasn't finished and he went on to identify what he called the real blockbuster in the paper. He quotes this section from a paper written

by virologists and published by the CDC and then explains what it means:

Therefore, we examined the capacity of SARS-CoV-2 to infect and replicate in several common primate and human cell lines, including human adenocarcinoma cells (A549), human liver cells (HUH 7.0), and human embryonic kidney cells (HEK-293T). In addition to Vero E6 and Vero CCL81 cells. ... Each cell line was inoculated at high multiplicity of infection and examined 24h post-infection.

No CPE was observed in any of the cell lines except in Vero cells, which grew to greater than 10 to the 7th power at 24 h post-infection. In contrast, HUH 7.0 and 293T showed only modest viral replication, and A549 cells were incompatible with SARS CoV-2 infection.

Cowan explains that when virologists attempt to prove infection they have three possible 'hosts' or models on which they can test. The first was humans. Exposure to humans was generally not done for ethical reasons and has never been done with SARS-CoV-2 or any coronavirus. The second possible host was animals. Cowan said that forgetting for a moment that they never actually use purified virus when exposing animals they do use solutions that they *claim* contain the virus. Exposure to animals has been done with SARS-CoV-2 in an experiment involving mice and this is what they found: *None of the wild (normal) mice got sick*. In a group of genetically-modified mice, a statistically insignificant number lost weight and had slightly bristled fur, but they experienced nothing like the illness called 'Covid-19'. Cowan said the third method – the one they mostly rely on – is to inoculate solutions they *say* contain the virus onto a variety of tissue cultures. This process had never been shown to kill tissue *unless* the sample material was starved of nutrients and poisoned as *part of the process*. Yes, incredibly, in tissue experiments designed to show the 'virus' is responsible for killing the tissue they starve the tissue of nutrients and add toxic drugs including antibiotics and they do not have control studies to see if it's the starvation and poisoning that is degrading the tissue rather than the 'virus' they allege to be in there somewhere. You want me to pinch you? Yep, I understand. Tom Cowan said this about the whole nonsensical farce as he explains what that quote from the CDC paper really means:

The shocking thing about the above quote is that using their own methods, the virologists found that solutions containing SARS-CoV-2 – even in high amounts – were NOT, I repeat NOT, infective to any of the three human tissue cultures they tested. In plain English, this means they proved, on their terms, that this 'new coronavirus' is not infectious to human beings. It is ONLY infective to monkey kidney cells, and only then when you add two potent drugs (gentamicin and amphotericin), known to be toxic to kidneys, to the mix.

My friends, read this again and again. These virologists, published by the CDC, performed a clear proof, on their terms, showing that the SARS-CoV-2 virus is harmless to human beings. That is the only possible conclusion, but, unfortunately, this result is not even mentioned in their conclusion. They simply say they can provide virus stocks cultured only on monkey Vero cells, thanks for coming.

Cowan concluded: 'If people really understood how this "science" was done, I would hope they would storm the gates and demand honesty, transparency and truth.' Dr Michael Yeadon, former Vice President and Chief Scientific Adviser at drug giant Pfizer has been a vocal critic of the 'Covid vaccine' and its potential for multiple harm. He said in an interview in April, 2021, that 'not one [vaccine] has the virus. He was asked why vaccines normally using a 'dead' version of a disease to activate the immune system were not used for 'Covid' and instead we had the synthetic methods of the 'mRNA Covid vaccine'. Yeadon said that to do the former 'you'd have to have some of [the virus] wouldn't you?' He added: 'No-one's got any – seriously.' Yeadon said that surely they couldn't have fooled the whole world for a year without having a virus, 'but oddly enough ask around – no one's got it'. He didn't know why with all the 'great labs' around the world that the virus had not been isolated – 'Maybe they've been too busy running bad PCR tests and vaccines that people don't need.' What is today called 'science' is not 'science' at all. Science is no longer what is, but whatever people can be manipulated to *believe* that it is. Real science has been hijacked by the Cult to dispense and produce the 'expert scientists' and contentions that suit the agenda of the Cult. How big-time this has happened with the 'Covid' hoax which is entirely based on fake science delivered by fake 'scientists' and fake 'doctors'. The human-caused climate change hoax is also entirely based on fake science delivered by fake 'scientists' and fake 'climate experts'. In both cases real

scientists, climate experts and doctors have their views suppressed and deleted by the Cult-owned science establishment, media and Silicon Valley. This is the 'science' that politicians claim to be 'following' and a common denominator of 'Covid' and climate are Cult psychopaths Bill Gates and his mate Klaus Schwab at the Gates-funded World Economic Forum. But, don't worry, it's all just a coincidence and absolutely nothing to worry about. *Zzzzzzzz*.

What is a 'virus' REALLY?

Dr Tom Cowan is one of many contesting the very existence of viruses let alone that they cause disease. This is understandable when there is no scientific evidence for a disease-causing 'virus'. German virologist Dr Stefan Lanka won a landmark case in 2017 in the German Supreme Court over his contention that there is no such thing as a measles virus. He had offered a big prize for anyone who could prove there is and Lanka won his case when someone sought to claim the money. There is currently a prize of more than 225,000 euros on offer from an Isolate Truth Fund for anyone who can prove the isolation of SARS-CoV-2 and its genetic substance. Lanka wrote in an article headed 'The Misconception Called Virus' that scientists think a 'virus' is causing tissue to become diseased and degraded when in fact it is the *processes they are using* which do that – not a 'virus'. Lanka has done an important job in making this point clear as Cowan did in his analysis of the CDC paper. Lanka says that all claims about viruses as disease-causing pathogens are wrong and based on 'easily recognisable, understandable and verifiable misinterpretations.' Scientists believed they were working with 'viruses' in their laboratories when they were really working with 'typical particles of specific dying tissues or cells …' Lanka said that the tissue decaying process claimed to be caused by a 'virus' still happens when no alleged 'virus' is involved. It's the *process* that does the damage and not a 'virus'. The genetic sample is deprived of nutrients, removed from its energy supply through removal from the body and then doused in toxic antibiotics to remove any bacteria. He confirms again that establishment scientists do not (pinch me)

conduct control experiments to see if this is the case and if they did they would see the claims that 'viruses' are doing the damage is nonsense. He adds that during the measles 'virus' court case he commissioned an independent laboratory to perform just such a control experiment and the result was that the tissues and cells died in the exact same way as with alleged 'infected' material. This is supported by a gathering number of scientists, doctors and researchers who reject what is called 'germ theory' or the belief in the body being infected by contagious sources emitted by other people. Researchers Dawn Lester and David Parker take the same stance in their highly-detailed and sourced book *What Really Makes You Ill – Why everything you thought you knew about disease is wrong* which was recommended to me by a number of medical professionals genuinely seeking the truth. Lester and Parker say there is no provable scientific evidence to show that a 'virus' can be transmitted between people or people and animals or animals and people:

> The definition also claims that viruses are the cause of many diseases, as if this has been definitively proven. But this is not the case; there is no original scientific evidence that definitively demonstrates that any virus is the cause of any disease. The burden of proof for any theory lies with those who proposed it; but none of the existing documents provides 'proof' that supports the claim that 'viruses' are pathogens.

Dr Tom Cowan employs one of his clever analogies to describe the process by which a 'virus' is named as the culprit for a disease when what is called a 'virus' is only material released by cells detoxing themselves from infiltration by chemical or radiation poisoning. The tidal wave of technologically-generated radiation in the 'smart' modern world plus all the toxic food and drink are causing this to happen more than ever. Deluded 'scientists' misread this as a gathering impact of what they wrongly label 'viruses'.

Paper can infect houses

Cowan said in an article for davidicke.com – with his tongue only mildly in his cheek – that he believed he had made a tremendous

discovery that may revolutionise science. He had discovered that small bits of paper are alive, 'well alive-ish', can 'infect' houses, and then reproduce themselves inside the house. The result was that this explosion of growth in the paper inside the house causes the house to explode, blowing it to smithereens. His evidence for this new theory is that in the past months he had carefully examined many of the houses in his neighbourhood and found almost no scraps of paper on the lawns and surrounds of the house. There was an occasional stray label, but nothing more. Then he would return to these same houses a week or so later and with a few, not all of them, particularly the old and decrepit ones, he found to his shock and surprise they were littered with stray bits of paper. He knew then that the paper had infected these houses, made copies of itself, and blew up the house. A young boy on a bicycle at one of the sites told him he had seen a demolition crew using dynamite to explode the house the previous week, but Cowan dismissed this as the idle thoughts of silly boys because 'I was on to something big'. He was on to how 'scientists' mistake genetic material in the detoxifying process for something they call a 'virus'. Cowan said of his house and paper story:

> If this sounds crazy to you, it's because it should. This scenario is obviously nuts. But consider this admittedly embellished, for effect, current viral theory that all scientists, medical doctors and virologists currently believe.

He takes the example of the 'novel SARS-Cov2' virus to prove the point. First they take someone with an undefined illness called 'Covid-19' and don't even attempt to find any virus in their sputum. Never mind the scientists still describe how this 'virus', which they have not located attaches to a cell receptor, injects its genetic material, in 'Covid's' case, RNA, into the cell. The RNA once inserted exploits the cell to reproduce itself and makes 'thousands, nay millions, of copies of itself … Then it emerges victorious to claim its next victim':

If you were to look in the scientific literature for proof, actual scientific proof, that uniform SARS-CoV2 viruses have been properly isolated from the sputum of a sick person, that actual spike proteins could be seen protruding from the virus (which has not been found), you would find that such evidence doesn't exist.

If you go looking in the published scientific literature for actual pictures, proof, that these spike proteins or any viral proteins are ever attached to any receptor embedded in any cell membrane, you would also find that no such evidence exists. If you were to look for a video or documented evidence of the intact virus injecting its genetic material into the body of the cell, reproducing itself and then emerging victorious by budding off the cell membrane, you would find that no such evidence exists.

The closest thing you would find is electron micrograph pictures of cellular particles, possibly attached to cell debris, both of which to be seen were stained by heavy metals, a process that completely distorts their architecture within the living organism. This is like finding bits of paper stuck to the blown-up bricks, thereby proving the paper emerged by taking pieces of the bricks on its way out.

The Enders baloney

Cowan describes the 'Covid' story as being just as make-believe as his paper story and he charts back this fantasy to a Nobel Prize winner called John Enders (1897-1985), an American biomedical scientist who has been dubbed 'The Father of Modern Vaccines'. Enders is claimed to have 'discovered' the process of the viral culture which 'proved' that a 'virus' caused measles. Cowan explains how Enders did this 'by using the EXACT same procedure that has been followed by every virologist to find and characterize every new virus since 1954'. Enders took throat swabs from children with measles and immersed them in 2ml of milk. Penicillin (100u/ml) and the antibiotic streptomycin (50,g/ml) were added and the whole mix was centrifuged – rotated at high speed to separate large cellular debris from small particles and molecules as with milk and cream, for example. Cowan says that if the aim is to find little particles of genetic material ('viruses') in the snot from children with measles it would seem that the last thing you would do is mix the snot with other material – milk –that also has genetic material. 'How are you ever going to know whether whatever you found came from the snot or the milk?' He points out that streptomycin is a 'nephrotoxic' or poisonous-to-the-kidney drug. You will see the relevance of that

shortly. Cowan says that it gets worse, much worse, when Enders describes the culture medium upon which the virus 'grows': 'The culture medium consisted of bovine amniotic fluid (90%), beef embryo extract (5%), horse serum (5%), antibiotics and phenol red as an indicator of cell metabolism.' Cowan asks incredulously: 'Did he just say that the culture medium also contained fluids and tissues that are themselves rich sources of genetic material?' The genetic cocktail, or 'medium', is inoculated onto tissue and cells from rhesus monkey *kidney* tissue. This is where the importance of streptomycin comes in and currently-used antimicrobials and other drugs that are *poisonous to kidneys* and used in ALL modern viral cultures (e.g. gentamicin, streptomycin, and amphotericin). Cowan asks: 'How are you ever going to know from this witch's brew where any genetic material comes from as we now have five different sources of rich genetic material in our mix?' Remember, he says, that all genetic material, whether from monkey kidney tissues, bovine serum, milk, etc., is made from the exact same components. The same central question returns: 'How are you possibly going to know that it was the virus that killed the kidney tissue and not the toxic antibiotic and starvation rations on which you are growing the tissue?' John Enders answered the question himself – *you can't*:

A second agent was obtained from an uninoculated culture of monkey kidney cells. The cytopathic changes [death of the cells] it induced in the unstained preparations could not be distinguished with confidence from the viruses isolated from measles.

The death of the cells ('cytopathic changes') happened in exactly the same manner, whether they inoculated the kidney tissue with the measles snot or not, Cowan says. 'This is evidence that the destruction of the tissue, the very proof of viral causation of illness, was not caused by anything in the snot because they saw the same destructive effect when the snot was not even used … the cytopathic, i.e., cell-killing, changes come from the process of the culture itself, not from any virus in any snot, period.' Enders quotes in his 1957 paper a virologist called Ruckle as reporting similar findings 'and in addition has isolated an agent from monkey kidney tissue that is so

far indistinguishable from human measles virus'. In other words, Cowan says, these particles called 'measles viruses' are simply and clearly breakdown products of the starved and poisoned tissue. For measles 'virus' see all 'viruses' including the so-called 'Covid virus'. Enders, the 'Father of Modern Vaccines', also said:

There is a potential risk in employing cultures of primate cells for the production of vaccines composed of attenuated virus, since the presence of other agents possibly latent in primate tissues cannot be definitely excluded by any known method.

Cowan further quotes from a paper published in the journal *Viruses* in May, 2020, while the 'Covid pandemic' was well underway in the media if not in reality. 'EVs' here refers to particles of genetic debris from our own tissues, such as exosomes of which more in a moment: 'The remarkable resemblance between EVs and viruses has caused quite a few problems in the studies focused on the analysis of EVs released during viral infections.' Later the paper adds that to date a reliable method that can actually guarantee a complete separation (of EVs from viruses) DOES NOT EXIST. This was published at a time when a fairy tale 'virus' was claimed in total certainty to be causing a fairy tale 'viral disease' called 'Covid-19' – a fairy tale that was already well on the way to transforming human society in the image that the Cult has worked to achieve for so long. Cowan concludes his article:

To summarize, there is no scientific evidence that pathogenic viruses exist. What we think of as 'viruses' are simply the normal breakdown products of dead and dying tissues and cells. When we are well, we make fewer of these particles; when we are starved, poisoned, suffocated by wearing masks, or afraid, we make more.

There is no engineered virus circulating and making people sick. People in laboratories all over the world are making genetically modified products to make people sick. These are called vaccines. There is no virome, no 'ecosystem' of viruses, viruses are not 8%, 50% or 100 % of our genetic material. These are all simply erroneous ideas based on the misconception called a virus.

What is 'Covid'? Load of bollocks

The background described here by Cowan and Lanka was emphasised in the first video presentation that I saw by Dr Andrew Kaufman when he asked whether the 'Covid virus' was in truth a natural defence mechanism of the body called 'exosomes'. These are released by cells when in states of toxicity – see the same themes returning over and over. They are released ever more profusely as chemical and radiation toxicity increases and think of the potential effect therefore of 5G alone as its destructive frequencies infest the human energetic information field with a gathering pace (5G went online in Wuhan in 2019 as the 'virus' emerged). I'll have more about this later. Exosomes transmit a warning to the rest of the body that 'Houston, we have a problem'. Kaufman presented images of exosomes and compared them with 'Covid' under an electron microscope and the similarity was remarkable. They both attach to the same cell receptors (*claimed* in the case of 'Covid'), contain the same genetic material in the form of RNA or ribonucleic acid, and both are found in 'viral cell cultures' with damaged or dying cells. James Hildreth MD, President and Chief Executive Officer of the Meharry Medical College at Johns Hopkins, said: 'The virus is fully an exosome in every sense of the word.' Kaufman's conclusion was that there is no 'virus': 'This entire pandemic is a completely manufactured crisis … there is no evidence of anyone dying from [this] illness.' Dr Tom Cowan and Sally Fallon Morell, authors of *The Contagion Myth*, published a statement with Dr Kaufman in February, 2021, explaining why the 'virus' does not exist and you can read it that in full in the Appendix.

'Virus' theory can be traced to the 'cell theory' in 1858 of German physician Rudolf Virchow (1821-1920) who contended that disease originates from a single cell infiltrated by a 'virus'. Dr Stefan Lanka said that findings and insights with respect to the structure, function and central importance of tissues in the creation of life, which were already known in 1858, comprehensively refute the cell theory. Virchow ignored them. We have seen the part later played by John Enders in the 1950s and Lanka notes that infection theories were only established as a global dogma through the policies and

eugenics of the Third Reich in Nazi Germany (creation of the same Sabbatian cult behind the 'Covid' hoax). Lanka said: 'Before 1933, scientists dared to contradict this theory; after 1933, these critical scientists were silenced'. Dr Tom Cowan's view is that ill-heath is caused by too much of something, too little of something, or toxification from chemicals and radiation – not contagion. We must also highlight as a major source of the 'virus' theology a man still called the 'Father of Modern Virology' – Thomas Milton Rivers (1888-1962). There is no way given the Cult's long game policy that it was a coincidence for the 'Father of Modern Virology' to be director of the Rockefeller Institute for Medical Research from 1937 to 1956 when he is credited with making the Rockefeller Institute a leader in 'viral research'. Cult Rockefellers were the force behind the creation of Big Pharma 'medicine', established the World Health Organisation in 1948, and have long and close associations with the Gates family that now runs the WHO during the pandemic hoax through mega-rich Cult gofer and psychopath Bill Gates.

Only a Renegade Mind can see through all this bullshit by asking the questions that need to be answered, not taking 'no' or prevarication for an answer, and certainly not hiding from the truth in fear of speaking it. Renegade Minds have always changed the world for the better and they will change this one no matter how bleak it may currently appear to be.

CHAPTER SIX

Sequence of deceit

If you tell the truth, you don't have to remember anything
Mark Twain

Against the background that I have laid out this far the sequence that took us from an invented 'virus' in Cult-owned China in late 2019 to the fascist transformation of human society can be seen and understood in a whole new context.

We were told that a deadly disease had broken out in Wuhan and the world media began its campaign (coordinated by behavioural psychologists as we shall see) to terrify the population into unquestioning compliance. We were shown images of Chinese people collapsing in the street which never happened in the West with what was supposed to be the same condition. In the earliest days when alleged cases and deaths were few the fear register was hysterical in many areas of the media and this would expand into the common media narrative across the world. The real story was rather different, but we were never told that. The Chinese government, one of the Cult's biggest centres of global operation, said they had discovered a new illness with flu-like and pneumonia-type symptoms in a city with such toxic air that it is overwhelmed with flu-like symptoms, pneumonia and respiratory disease. Chinese scientists said it was a new – 'novel' – coronavirus which they called Sars-Cov-2 and that it caused a disease they labelled 'Covid-19'. There was no evidence for this and the 'virus' has never to this day been isolated, purified and its genetic code established from that. It

was from the beginning a computer-generated fiction. Stories of Chinese whistleblowers saying the number of deaths was being supressed or that the 'new disease' was related to the Wuhan bio-lab misdirected mainstream and alternative media into cul-de-sacs to obscure the real truth – there was no 'virus'.

Chinese scientists took genetic material from the lung fluid of just a few people and said they had found a 'new' disease when this material had a wide range of content. There was no evidence for a 'virus' for the very reasons explained in the last two chapters. The 'virus' has never been shown to (a) exist and (b) cause any disease. People were diagnosed on symptoms that are so widespread in Wuhan and polluted China and with a PCR test that can't detect infectious disease. On this farce the whole global scam was sold to the rest of the world which would also diagnose respiratory disease as 'Covid-19' from symptoms alone or with a PCR test not testing for a 'virus'. Flu miraculously disappeared *worldwide* in 2020 and into 2021 as it was redesignated 'Covid-19'. It was really the same old flu with its 'flu-like' symptoms attributed to 'flu-like' 'Covid-19'. At the same time with very few exceptions the Chinese response of draconian lockdown and fascism was the chosen weapon to respond across the West as recommended by the Cult-owned Tedros at the Cult-owned World Health Organization run by the Cult-owned Gates. All was going according to plan. Chinese scientists – everything in China is controlled by the Cult-owned government – compared their contaminated RNA lung-fluid material with other RNA sequences and said it appeared to be just under 80 percent identical to the SARS-CoV-1 'virus' claimed to be the cause of the SARS (severe acute respiratory syndrome) 'outbreak' in 2003. They decreed that because of this the 'new virus' had to be related and they called it SARS-CoV-2. There are some serious problems with this assumption and *assumption* was all it was. Most 'factual' science turns out to be assumptions repeated into everyone-knows-that. A match of under 80-percent is meaningless. Dr Kaufman makes the point that there's a *96 percent* genetic correlation between humans and chimpanzees, but 'no one would say our genetic material is part

of the chimpanzee family'. Yet the Chinese authorities were claiming that a much lower percentage, less than 80 percent, proved the existence of a new 'coronavirus'. For goodness sake human DNA is 60 percent similar to a *banana*.

You are feeling sleepy

The entire 'Covid' hoax is a global Psyop, a psychological operation to program the human mind into believing and fearing a complete fantasy. A crucial aspect of this was what *appeared* to happen in Italy. It was all very well streaming out daily images of an alleged catastrophe in Wuhan, but to the Western mind it was still on the other side of the world in a very different culture and setting. A reaction of 'this could happen to me and my family' was still nothing like as intense enough for the mind-doctors. The Cult needed a Western example to push people over that edge and it chose Italy, one of its major global locations going back to the Roman Empire. An Italian 'Covid' crisis was manufactured in a particular area called Lombardy which just happens to be notorious for its toxic air and therefore respiratory disease. Wuhan, China, déjà vu. An hysterical media told horror stories of Italians dying from 'Covid' in their droves and how Lombardy hospitals were being overrun by a tidal wave of desperately ill people needing treatment after being struck down by the 'deadly virus'. Here was the psychological turning point the Cult had planned. Wow, if this is happening in Italy, the Western mind concluded, this indeed could happen to me and my family. Another point is that Italian authorities responded by following the Chinese blueprint so vehemently recommended by the Cult-owned World Health Organization. They imposed fascistic lockdowns on the whole country viciously policed with the help of surveillance drones sweeping through the streets seeking out anyone who escaped from mass house arrest. Livelihoods were destroyed and psychology unravelled in the way we have witnessed since in all lockdown countries. Crucial to the plan was that Italy responded in this way to set the precedent of suspending freedom and imposing fascism in a 'Western liberal democracy'. I emphasised in an

animated video explanation on davidicke.com posted in the summer of 2020 how important it was to the Cult to expand the Chinese lockdown model across the West. Without this, and the bare-faced lie that non-symptomatic people could still transmit a 'disease' they didn't have, there was no way locking down the whole population, sick and not sick, could be pulled off. At just the right time and with no evidence Cult operatives and gofers claimed that people without symptoms could pass on the 'disease'. In the name of protecting the 'vulnerable' like elderly people, who lockdowns would kill by the tens of thousands, we had for the first time healthy people told to isolate as well as the sick. The great majority of people who tested positive had no symptoms because there was nothing wrong with them. It was just a trick made possible by a test not testing for the 'virus'.

Months after my animated video the Gates-funded Professor Neil Ferguson at the Gates-funded Imperial College confirmed that I was right. He didn't say it in those terms, naturally, but he did say it. Ferguson will enter the story shortly for his outrageously crazy 'computer models' that led to Britain, the United States and many other countries following the Chinese and now Italian methods of response. Put another way, following the Cult script. Ferguson said that SAGE, the UK government's scientific advisory group which has controlled 'Covid' policy from the start, wanted to follow the Chinese lockdown model (while they all continued to work and be paid), but they wondered if they could possibly, in Ferguson's words, 'get away with it in Europe'. 'Get away with it'? Who the hell do these moronic, arrogant people think they are? This appalling man Ferguson said that once Italy went into national lockdown they realised they, too, could mimic China:

> It's a communist one-party state, we said. We couldn't get away with it in Europe, we thought … and then Italy did it. And we realised we could. Behind this garbage from Ferguson is a simple fact: Doing the same as China in every country was the plan from the start and Ferguson's 'models' would play a central role in achieving that. It's just a coincidence, of course, and absolutely nothing to worry your little head about.

Oops, sorry, our mistake

Once the Italian segment of the Psyop had done the job it was designed to do a very different story emerged. Italian authorities revealed that 99 percent of those who had 'died from Covid-19' in Italy had one, two, three, or more 'co-morbidities' or illnesses and health problems that could have ended their life. The US Centers for Disease Control and Prevention (CDC) published a figure of 94 percent for Americans dying of 'Covid' while having other serious medical conditions – on average two to three (some five or six) other potential causes of death. In terms of death from an unproven 'virus' I say it is 100 percent. The other one percent in Italy and six percent in the US would presumably have died from 'Covid's' flu-like symptoms with a range of other possible causes in conjunction with a test not testing for the 'virus'. Fox News reported that even more startling figures had emerged in one US county in which 410 of 422 deaths attributed to 'Covid-19' had other potentially deadly health conditions. The Italian National Health Institute said later that the average age of people dying with a 'Covid-19' diagnosis in Italy was about 81. Ninety percent were over 70 with ten percent over 90. In terms of other reasons to die some 80 percent had two or more chronic diseases with half having three or more including cardiovascular problems, diabetes, respiratory problems and cancer. Why is the phantom 'Covid-19' said to kill overwhelmingly old people and hardly affect the young? Old people continually die of many causes and especially respiratory disease which you can re-diagnose 'Covid-19' while young people die in tiny numbers by comparison and rarely of respiratory disease. Old people 'die of Covid' because they die of other things that can be redesignated 'Covid' and it really is that simple.

Flu has flown

The blueprint was in place. Get your illusory 'cases' from a test not testing for the 'virus' and redesignate other causes of death as 'Covid-19'. You have an instant 'pandemic' from something that is nothing more than a computer-generated fiction. With near-on a

billion people having 'flu-like' symptoms every year the potential was limitless and we can see why flu quickly and apparently miraculously disappeared *worldwide* by being diagnosed 'Covid-19'. The painfully bloody obvious was explained away by the childlike media in headlines like this in the UK '*Independent*': 'Not a single case of flu detected by Public Health England this year as Covid restrictions suppress virus'. I kid you not. The masking, social distancing and house arrest that did not make the 'Covid virus' disappear somehow did so with the 'flu virus'. Even worse the article, by a bloke called Samuel Lovett, suggested that maybe the masking, sanitising and other 'Covid' measures should continue to keep the flu away. With a ridiculousness that disturbs your breathing (it's 'Covid-19') the said Lovett wrote: 'With widespread social distancing and mask-wearing measures in place throughout the UK, the usual routes of transmission for influenza have been blocked.' He had absolutely no evidence to support that statement, but look at the consequences of him acknowledging the obvious. With flu not disappearing at all and only being relabelled 'Covid-19' he would have to contemplate that 'Covid' was a hoax on a scale that is hard to imagine. You need guts and commitment to truth to even go there and that's clearly something Samuel Lovett does not have in abundance. He would never have got it through the editors anyway.

Tens of thousands die in the United States alone every winter from flu including many with pneumonia complications. CDC figures record *45 million* Americans diagnosed with flu in 2017-2018 of which 61,000 died and some reports claim 80,000. Where was the same hysteria then that we have seen with 'Covid-19'? Some 250,000 Americans are admitted to hospital with pneumonia every year with about 50,000 cases proving fatal. About 65 million suffer respiratory disease every year and three million deaths makes this the third biggest cause of death worldwide. You only have to redesignate a portion of all these people 'Covid-19' and you have an instant global pandemic or the *appearance* of one. Why would doctors do this? They are told to do this and all but a few dare not refuse those who must be obeyed. Doctors in general are not researching their own

knowledge and instead take it direct and unquestioned from the authorities that own them and their careers. The authorities say they must now diagnose these symptoms 'Covid-19' and not flu, or whatever, and they do it. Dark suits say put 'Covid-19' on death certificates no matter what the cause of death and the doctors do it. Renegade Minds don't fall for the illusion that doctors and medical staff are all highly-intelligent, highly-principled, seekers of medical truth. *Some are*, but not the majority. They are repeaters, gofers, and yes sir, no sir, purveyors of what the system demands they purvey. The 'Covid' con is not merely confined to diseases of the lungs. Instructions to doctors to put 'Covid-19' on death certificates for anyone dying of *anything* within 28 days (or much more) of a positive test not testing for the 'virus' opened the floodgates. The term dying *with* 'Covid' and not *of* 'Covid' was coined to cover the truth. Whether it was a *with* or an *of* they were all added to the death numbers attributed to the 'deadly virus' compiled by national governments and globally by the Gates-funded Johns Hopkins operation in the United States that was so involved in those 'pandemic' simulations. Fraudulent deaths were added to the ever-growing list of fraudulent 'cases' from false positives from a false test. No wonder Professor Walter Ricciardi, scientific advisor to the Italian minister of health, said after the Lombardy hysteria had done its job that 'Covid' death rates were due to Italy having the second oldest population in the world and to *how hospitals record deaths*:

The way in which we code deaths in our country is very generous in the sense that all the people who die in hospitals with the coronavirus are deemed to be dying of the coronavirus. On re-evaluation by the National Institute of Health, only 12 per cent of death certificates have shown a direct causality from coronavirus, while 88 per cent of patients who have died have at least one pre-morbidity – many had two or three.

This is extraordinary enough when you consider the propaganda campaign to use Italy to terrify the world, but how can they even say twelve percent were genuine when the 'virus' has not been shown to exist, its 'code' is a computer program, and diagnosis comes from a test not testing for it? As in China, and soon the world, 'Covid-19' in

Italy was a redesignation of diagnosis. Lies and corruption were to become the real 'pandemic' fuelled by a pathetically-compliant medical system taking its orders from the tiny few at the top of their national hierarchy who answered to the World Health Organization which answers to Gates and the Cult. Doctors were told – ordered – to diagnose a particular set of symptoms 'Covid-19' and put that on the death certificate for any cause of death if the patient had tested positive with a test not testing for the virus or had 'Covid' symptoms like the flu. The United States even introduced big financial incentives to manipulate the figures with hospitals receiving £4,600 from the Medicare system for diagnosing someone with regular pneumonia, $13,000 if they made the diagnosis from the same symptoms 'Covid-19' pneumonia, and $39, 000 if they put a 'Covid' diagnosed patient on a ventilator that would almost certainly kill them. A few – painfully and pathetically few – medical whistleblowers revealed (before Cult-owned YouTube deleted their videos) that they had been instructed to 'let the patient crash' and put them straight on a ventilator instead of going through a series of far less intrusive and dangerous methods as they would have done before the pandemic hoax began and the financial incentives kicked in. We are talking cold-blooded murder given that ventilators are so damaging to respiratory systems they are usually the last step before heaven awaits. Renegade Minds never fall for the belief that people in white coats are all angels of mercy and cannot be full-on psychopaths. I have explained in detail in *The Answer* how what I am describing here played out across the world coordinated by the World Health Organization through the medical hierarchies in almost every country.

Medical scientist calls it

Information about the non-existence of the 'virus' began to emerge for me in late March, 2020, and mushroomed after that. I was sent an email by Sir Julian Rose, a writer, researcher, and organic farming promotor, from a medical scientist friend of his in the United States. Even at that early stage in March the scientist was able to explain

how the 'Covid' hoax was being manipulated. He said there were no reliable tests for a specific 'Covid-19 virus' and nor were there any reliable agencies or media outlets for reporting numbers of actual 'Covid-19' cases. We have seen in the long period since then that he was absolutely right. 'Every action and reaction to Covid-19 is based on totally flawed data and we simply cannot make accurate assessments,' he said. Most people diagnosed with 'Covid-19' were showing nothing more than cold and flu-like symptoms 'because most coronavirus strains *are* nothing more than cold/flu-like symptoms'. We had farcical situations like an 84-year-old German man testing positive for 'Covid-19' and his nursing home ordered to quarantine only for him to be found to have a common cold. The scientist described back then why PCR tests and what he called the 'Mickey Mouse test kits' were useless for what they were claimed to be identifying. 'The idea these kits can isolate a specific virus like Covid-19 is nonsense,' he said. Significantly, he pointed out that 'if you want to create a totally false panic about a totally false pandemic – pick a coronavirus'. This is exactly what the Cult-owned Gates, World Economic Forum and Johns Hopkins University did with their Event 201 'simulation' followed by their real-life simulation called the 'pandemic'. The scientist said that all you had to do was select the sickest of people with respiratory-type diseases in a single location – 'say Wuhan' – and administer PCR tests to them. You can then claim that anyone showing 'viral sequences' similar to a coronavirus 'which will inevitably be quite a few' is suffering from a 'new' disease:

> Since you already selected the sickest flu cases a fairly high proportion of your sample will go on to die. You can then say this 'new' virus has a CFR [case fatality rate] higher than the flu and use this to infuse more concern and do more tests which will of course produce more 'cases', which expands the testing, which produces yet more 'cases' and so on and so on. Before long you have your 'pandemic', and all you have done is use a simple test kit trick to convert the worst flu and pneumonia cases into something new that doesn't ACTUALLY EXIST [my emphasis].

He said that you then 'just run the same scam in other countries' and make sure to keep the fear message running high 'so that people

will feel panicky and less able to think critically'. The only problem to overcome was the fact *there is no* actual new deadly pathogen and only regular sick people. This meant that deaths from the 'new deadly pathogen' were going to be way too low for a real new deadly virus pandemic, but he said this could be overcome in the following ways – all of which would go on to happen:

1. You can claim this is just the beginning and more deaths are imminent [you underpin this with fantasy 'computer projections']. Use this as an excuse to quarantine everyone and then claim the quarantine prevented the expected millions of dead.

2. You can [say that people] 'minimizing' the dangers are irresponsible and bully them into not talking about numbers.

3. You can talk crap about made up numbers hoping to blind people with pseudoscience.

4. You can start testing well people (who, of course, will also likely have shreds of coronavirus [RNA] in them) and thus inflate your 'case figures' with 'asymptomatic carriers' (you will of course have to spin that to sound deadly even though any virologist knows the more symptom-less cases you have the less deadly is your pathogen).

The scientist said that if you take these simple steps 'you can have your own entirely manufactured pandemic up and running in weeks'. His analysis made so early in the hoax was brilliantly prophetic of what would actually unfold. Pulling all the information together in these recent chapters we have this is simple 1, 2, 3, of how you can delude virtually the entire human population into believing in a 'virus' that doesn't exist:

- A 'Covid case' is someone who tests positive with a test not testing for the 'virus'.

- A 'Covid death' is someone who dies of *any cause* within 28 days (or much longer) of testing positive with a test not testing for the 'virus.

- Asymptomatic means there is nothing wrong with you, but they claim you can pass on what you don't have to justify locking

down (quarantining) healthy people in totality.

The foundations of the hoax are that simple. A study involving ten million people in Wuhan, published in November, 2020, demolished the whole lie about those without symptoms passing on the 'virus'. They found '300 asymptomatic cases' and traced their contacts to find that not one of them was detected with the 'virus'. 'Asymptomatic' patients and their contacts were isolated for no less than two weeks and nothing changed. I know it's all crap, but if you are going to claim that those without symptoms can transmit 'the virus' then you must produce evidence for that and they never have. Even World Health Organization official Dr Maria Van Kerkhove, head of the emerging diseases and zoonosis unit, said as early as June, 2020, that she doubted the validity of asymptomatic transmission. She said that 'from the data we have, it still seems to be rare that an asymptomatic person actually transmits onward to a secondary individual' and by 'rare' she meant that she couldn't cite any case of asymptomatic transmission.

The Ferguson factor

The problem for the Cult as it headed into March, 2020, when the script had lockdown due to start, was that despite all the manipulation of the case and death figures they still did not have enough people alleged to have died from 'Covid' to justify mass house arrest. This was overcome in the way the scientist described: 'You can claim this is just the beginning and more deaths are imminent … Use this as an excuse to quarantine everyone and then claim the quarantine prevented the expected millions of dead.' Enter one Professor Neil Ferguson, the Gates-funded 'epidemiologist' at the Gates-funded Imperial College in London. Ferguson is Britain's Christian Drosten in that he has a dire record of predicting health outcomes, but is still called upon to advise government on the next health outcome when another 'crisis' comes along. This may seem to be a strange and ridiculous thing to do. Why would you keep turning for policy guidance to people who have a history of being

monumentally wrong? Ah, but it makes sense from the Cult point of view. These 'experts' keep on producing predictions that suit the Cult agenda for societal transformation and so it was with Neil Ferguson as he revealed his horrific (and clearly insane) computer model predictions that allowed lockdowns to be imposed in Britain, the United States and many other countries. Ferguson does not have even an A-level in biology and would appear to have no formal training in computer modelling, medicine or epidemiology, according to Derek Winton, an MSc in Computational Intelligence. He wrote an article somewhat aghast at what Ferguson did which included taking no account of respiratory disease 'seasonality' which means it is far worse in the winter months. Who would have thought that respiratory disease could be worse in the winter? Well, certainly not Ferguson.

The massively China-connected Imperial College and its bizarre professor provided the excuse for the long-incubated Chinese model of human control to travel westward at lightning speed. Imperial College confirms on its website that it collaborates with the Chinese Research Institute; publishes more than 600 research papers every year with Chinese research institutions; has 225 Chinese staff; 2,600 Chinese students – the biggest international group; 7,000 former students living in China which is the largest group outside the UK; and was selected for a tour by China's President Xi Jinping during his state visit to the UK in 2015. The college takes major donations from China and describes itself as the UK's number one university collaborator with Chinese research institutions. The China communist/fascist government did not appear phased by the woeful predictions of Ferguson and Imperial when during the lockdown that Ferguson induced the college signed a five-year collaboration deal with China tech giant Huawei that will have Huawei's indoor 5G network equipment installed at the college's West London tech campus along with an 'AI cloud platform'. The deal includes Chinese sponsorship of Imperial's Venture Catalyst entrepreneurship competition. Imperial is an example of the enormous influence the Chinese government has within British and North American

universities and research centres – and further afield. Up to 200 academics from more than a dozen UK universities are being investigated on suspicion of 'unintentionally' helping the Chinese government build weapons of mass destruction by 'transferring world-leading research in advanced military technology such as aircraft, missile designs and cyberweapons'. Similar scandals have broken in the United States, but it's all a coincidence. Imperial College serves the agenda in many other ways including the promotion of every aspect of the United Nations Agenda 21/2030 (the Great Reset) and produced computer models to show that human-caused 'climate change' is happening when in the real world it isn't. Imperial College is driving the climate agenda as it drives the 'Covid' agenda (both Cult hoaxes) while Patrick Vallance, the UK government's Chief Scientific Adviser on 'Covid', was named Chief Scientific Adviser to the UN 'climate change' conference known as COP26 hosted by the government in Glasgow, Scotland. 'Covid' and 'climate' are fundamentally connected.

Professor Woeful

From Imperial's bosom came Neil Ferguson still advising government despite his previous disasters and it was announced early on that he and other key people like UK Chief Medical Adviser Chris Whitty had caught the 'virus' as the propaganda story was being sold. Somehow they managed to survive and we had Prime Minister Boris Johnson admitted to hospital with what was said to be a severe version of the 'virus' in this same period. His whole policy and demeanour changed when he returned to Downing Street. It's a small world with these government advisors – especially in their communal connections to Gates – and Ferguson had partnered with Whitty to write a paper called 'Infectious disease: Tough choices to reduce Ebola transmission' which involved another scare-story that didn't happen. Ferguson's 'models' predicted that up to150, 000 could die from 'mad cow disease', or BSE, and its version in sheep if it was transmitted to humans. BSE was not transmitted and instead triggered by an organophosphate pesticide used to treat a pest on

cows. Fewer than 200 deaths followed from the human form. Models by Ferguson and his fellow incompetents led to the unnecessary culling of millions of pigs, cattle and sheep in the foot and mouth outbreak in 2001 which destroyed the lives and livelihoods of farmers and their families who had often spent decades building their herds and flocks. Vast numbers of these animals did not have foot and mouth and had no contact with the infection. Another 'expert' behind the cull was Professor Roy Anderson, a computer modeller at Imperial College specialising in the epidemiology of *human*, not animal, disease. Anderson has served on the Bill and Melinda Gates Grand Challenges in Global Health advisory board and chairs another Gates-funded organisation. Gates is everywhere.

In a precursor to the 'Covid' script Ferguson backed closing schools 'for prolonged periods' over the swine flu 'pandemic' in 2009 and said it would affect a third of the world population if it continued to spread at the speed he claimed to be happening. His mates at Imperial College said much the same and a news report said: 'One of the authors, the epidemiologist and disease modeller Neil Ferguson, who sits on the World Health Organisation's emergency committee for the outbreak, said the virus had "full pandemic potential".' Professor Liam Donaldson, the Chris Whitty of his day as Chief Medical Officer, said the worst case could see 30 percent of the British people infected by swine flu with 65,000 dying. Ferguson and Donaldson were indeed proved correct when at the end of the year the number of deaths attributed to swine flu was 392. The term 'expert' is rather liberally applied unfortunately, not least to complete idiots. Swine flu 'projections' were great for GlaxoSmithKline (GSK) as millions rolled in for its Pandemrix influenza vaccine which led to brain damage with children most affected. The British government (taxpayers) paid out more than £60 million in compensation after GSK was given immunity from prosecution. Yet another 'Covid' déjà vu. Swine flu was supposed to have broken out in Mexico, but Dr Wolfgang Wodarg, a German doctor, former member of parliament and critic of the 'Covid' hoax, observed 'the spread of swine flu' in Mexico City at the time. He

said: 'What we experienced in Mexico City was a very mild flu which did not kill more than usual – which killed even fewer people than usual.' Hyping the fear against all the facts is not unique to 'Covid' and has happened many times before. Ferguson is reported to have over-estimated the projected death toll of bird flu (H5N1) by some three million-fold, but bird flu vaccine makers again made a killing from the scare. This is some of the background to the Neil Ferguson who produced the perfectly-timed computer models in early 2020 predicting that half a million people would die in Britain without draconian lockdown and 2.2 million in the United States. Politicians panicked, people panicked, and lockdowns of alleged short duration were instigated to 'flatten the curve' of cases gleaned from a test not testing for the 'virus'. I said at the time that the public could forget the 'short duration' bit. This was an agenda to destroy the livelihoods of the population and force them into mass control through dependency and there was going to be nothing 'short' about it. American researcher Daniel Horowitz described the consequences of the 'models' spewed out by Gates-funded Ferguson and Imperial College:

> What led our government and the governments of many other countries into panic was a single Imperial College of UK study, funded by global warming activists, that predicted 2.2 million deaths if we didn't lock down the country. In addition, the reported 8-9% death rate in Italy scared us into thinking there was some other mutation of this virus that they got, which might have come here.
>
> Together with the fact that we were finally testing and had the ability to actually report new cases, we thought we were headed for a death spiral. But again … we can't flatten a curve if we don't know when the curve started.

How about it *never* started?

Giving them what they want

An investigation by German news outlet *Welt Am Sonntag (World on Sunday)* revealed how in March, 2020, the German government gathered together 'leading scientists from several research institutes and universities' and 'together, they were to produce a [modelling]

paper that would serve as legitimization for further tough political measures'. The Cult agenda was justified by computer modelling not based on evidence or reality; it was specifically constructed to justify the Cult demand for lockdowns all over the world to destroy the independent livelihoods of the global population. All these modellers and everyone responsible for the 'Covid' hoax have a date with a trial like those in Nuremberg after World War Two when Nazis faced the consequences of their war crimes. These corrupt-beyond-belief 'modellers' wrote the paper according to government instructions and it said that that if lockdown measures were lifted then up to one million Germans would die from 'Covid-19' adding that some would die 'agonizingly at home, gasping for breath' unable to be treated by hospitals that couldn't cope. All lies. No matter – it gave the Cult all that it wanted. What did long-time government 'modeller' Neil Ferguson say? If the UK and the United States didn't lockdown half a million would die in Britain and 2.2 million Americans. Anyone see a theme here? 'Modellers' are such a crucial part of the lockdown strategy that we should look into their background and follow the money. Researcher Rosemary Frei produced an excellent article headlined 'The Modelling-paper Mafiosi'. She highlights a guy called John Edmunds, a British epidemiologist, and professor in the Faculty of Epidemiology and Population Health at the London School of Hygiene & Tropical Medicine. He studied at Imperial College. Edmunds is a member of government 'Covid' advisory bodies which have been dictating policy, the New and Emerging Respiratory Virus Threats Advisory Group (NERVTAG) and the Scientific Advisory Group for Emergencies (SAGE).

Ferguson, another member of NERVTAG and SAGE, led the way with the original 'virus' and Edmunds has followed in the 'variant' stage and especially the so-called UK or Kent variant known as the 'Variant of Concern' (VOC) B.1.1.7. He said in a co-written report for the Centre for Mathematical modelling of Infectious Diseases at the London School of Hygiene and Tropical Medicine, with input from the Centre's 'Covid-19' Working Group, that there was 'a realistic

possibility that VOC B.1.1.7 is associated with an increased risk of death compared to non-VOC viruses'. Fear, fear, fear, get the vaccine, fear, fear, fear, get the vaccine. Rosemary Frei reveals that almost all the paper's authors and members of the modelling centre's 'Covid-19' Working Group receive funding from the Bill and Melinda Gates Foundation and/or the associated Gates-funded Wellcome Trust. The paper was published by e-journal *Medr χiv* which only publishes papers not peer-reviewed and the journal was established by an organisation headed by Facebook's Mark Zuckerberg and his missus. What a small world it is. Frei discovered that Edmunds is on the Scientific Advisory Board of the Coalition for Epidemic Preparedness Innovations (CEPI) which was established by the Bill and Melinda Gates Foundation, Klaus Schwab's Davos World Economic Forum and Big Pharma giant Wellcome. CEPI was 'launched in Davos [in 2017] to develop vaccines to stop future epidemics', according to its website. 'Our mission is to accelerate the development of vaccines against emerging infectious diseases and enable equitable access to these vaccines for people during outbreaks.' What kind people they are. Rosemary Frei reveals that Public Health England (PHE) director Susan Hopkins is an author of her organisation's non-peer-reviewed reports on 'new variants'. Hopkins is a professor of infectious diseases at London's Imperial College which is gifted tens of millions of dollars a year by the Bill and Melinda Gates Foundation. Gates-funded modelling disaster Neil Ferguson also co-authors Public Health England reports and he spoke in December, 2020, about the potential danger of the B.1.1.7. 'UK variant' promoted by Gates-funded modeller John Edmunds. When I come to the 'Covid vaccines' the 'new variants' will be shown for what they are – bollocks.

Connections, connections

All these people and modellers are lockdown-obsessed or, put another way, they demand what the Cult demands. Edmunds said in January, 2021, that to ease lockdowns too soon would be a disaster and they had to 'vaccinate much, much, much more widely than the

elderly'. Rosemary Frei highlights that Edmunds is married to Jeanne Pimenta who is described in a LinkedIn profile as director of epidemiology at GlaxoSmithKline (GSK) and she held shares in the company. Patrick Vallance, co-chair of SAGE and the government's Chief Scientific Adviser, is a former executive of GSK and has a deferred bonus of shares in the company worth £600,000. GSK has serious business connections with Bill Gates and is collaborating with mRNA-'vaccine' company CureVac to make 'vaccines' for the new variants that Edmunds is talking about. GSK is planning a 'Covid vaccine' with drug giant Sanofi. Puppet Prime Minister Boris Johnson announced in the spring of 2021 that up to 60 million vaccine doses were to be made at the GSK facility at Barnard Castle in the English North East. Barnard Castle, with a population of just 6,000, was famously visited in breach of lockdown rules in April, 2020, by Johnson aide Dominic Cummings who said that he drove there 'to test his eyesight' before driving back to London. Cummings would be better advised to test his integrity – not that it would take long. The GSK facility had nothing to do with his visit then although I'm sure Patrick Vallance would have been happy to arrange an introduction and some tea and biscuits. Ruthless psychopath Gates has made yet another fortune from vaccines in collaboration with Big Pharma companies and gushes at the phenomenal profits to be made from vaccines – more than a 20-to-1 return as he told one interviewer. Gates also tweeted in December, 2019, with the foreknowledge of what was coming: 'What's next for our foundation? I'm particularly excited about what the next year could mean for one of the best buys in global health: vaccines.'

Modeller John Edmunds is a big promotor of vaccines as all these people appear to be. He's the dean of the London School of Hygiene & Tropical Medicine's Faculty of Epidemiology and Population Health which is primarily funded by the Bill and Melinda Gates Foundation and the Gates-established and funded GAVI vaccine alliance which is the Gates vehicle to vaccinate the world. The organisation Doctors Without Borders has described GAVI as being 'aimed more at supporting drug-industry desires to promote new

products than at finding the most efficient and sustainable means for fighting the diseases of poverty'. But then that's why the psychopath Gates created it. John Edmunds said in a video that the London School of Hygiene & Tropical Medicine is involved in every aspect of vaccine development including large-scale clinical trials. He contends that mathematical modelling can show that vaccines protect individuals and society. That's on the basis of shit in and shit out, I take it. Edmunds serves on the UK Vaccine Network as does Ferguson and the government's foremost 'Covid' adviser, the grim-faced, dark-eyed Chris Whitty. The Vaccine Network says it works 'to support the government to identify and shortlist targeted investment opportunities for the most promising vaccines and vaccine technologies that will help combat infectious diseases with epidemic potential, and to address structural issues related to the UK's broader vaccine infrastructure'. Ferguson is acting Director of the Imperial College Vaccine Impact Modelling Consortium which has funding from the Bill and Melina Gates Foundation and the Gates-created GAVI 'vaccine alliance'. Anyone wonder why these characters see vaccines as the answer to every problem? Ferguson is wildly enthusiastic in his support for GAVI's campaign to vaccine children en masse in poor countries. You would expect someone like Gates who has constantly talked about the need to reduce the population to want to fund vaccines to keep more people alive. I'm sure that's why he does it. The John Edmunds London School of Hygiene & Tropical Medicine (LSHTM) has a Vaccines Manufacturing Innovation Centre which develops, tests and commercialises vaccines. Rosemary Frei writes:

> The vaccines centre also performs affiliated activities like combating 'vaccine hesitancy'. The latter includes the Vaccine Confidence Project. The project's stated purpose is, among other things, 'to provide analysis and guidance for early response and engagement with the public to ensure sustained confidence in vaccines and immunisation'. The Vaccine Confidence Project's director is LSHTM professor Heidi Larson. For more than a decade she's been researching how to combat vaccine hesitancy.

How the bloody hell can blokes like John Edmunds and Neil Ferguson with those connections and financial ties model 'virus' case

and death projections for the government and especially in a way that gives their paymasters like Gates exactly what they want? It's insane, but this is what you find throughout the world.

'Covid' is not dangerous, oops, wait, yes it is

Only days before Ferguson's nightmare scenario made Jackboot Johnson take Britain into a China-style lockdown to save us from a deadly 'virus' the UK government website gov.uk was reporting something very different to Ferguson on a page of official government guidance for 'high consequence infectious diseases (HCID)'. It said this about 'Covid-19':

As of 19 March 2020, COVID-19 *is no longer considered to be a high consequence infectious diseases (HCID) in the UK* [my emphasis]. The 4 nations public health HCID group made an interim recommendation in January 2020 to classify COVID-19 as an HCID. This was based on consideration of the UK HCID criteria about the virus and the disease with information available during the early stages of the outbreak.

Now that more is known about COVID-19, the public health bodies in the UK have reviewed the most up to date information about COVID-19 against the UK HCID criteria. They have determined that several features have now changed; in particular, more information is available about mortality rates (low overall), and there is now greater clinical awareness and a specific and sensitive laboratory test, the availability of which continues to increase. The Advisory Committee on Dangerous Pathogens (ACDP) is also of the opinion that COVID-19 should no longer be classified as an HCID.

Soon after the government had been exposed for downgrading the risk they upgraded it again and everyone was back to singing from the same Cult hymn book. Ferguson and his fellow Gates clones indicated that lockdowns and restrictions would have to continue until a Gates-funded vaccine was developed. Gates said the same because Ferguson and his like were repeating the Gates script which is the Cult script. 'Flatten the curve' became an ongoing nightmare of continuing lockdowns with periods in between of severe restrictions in pursuit of destroying independent incomes and had nothing to do with protecting health about which the Cult gives not a shit. Why wouldn't Ferguson be pushing a vaccine 'solution' when he's owned by vaccine-obsessive Gates who makes a fortune from them and

when Ferguson heads the Vaccine Impact Modelling Consortium at Imperial College funded by the Gates Foundation and GAVI, the 'vaccine alliance', created by Gates as his personal vaccine promotion operation? To compound the human catastrophe that Ferguson's 'models' did so much to create he was later exposed for breaking his own lockdown rules by having sexual liaisons with his married girlfriend Antonia Staats at his home while she was living at another location with her husband and children. Staats was a 'climate' activist and senior campaigner at the Soros-funded Avaaz which I wouldn't trust to tell me that grass is green. Ferguson had to resign as a government advisor over this hypocrisy in May, 2020, but after a period of quiet he was back being quoted by the ridiculous media on the need for more lockdowns and a vaccine rollout. Other government-advising 'scientists' from Imperial College' held the fort in his absence and said lockdown could be indefinite until a vaccine was found. The Cult script was being sung by the payrolled choir. I said there was no intention of going back to 'normal' when the 'vaccine' came because the 'vaccine' is part of a very different agenda that I will discuss in Human 2.0. Why would the Cult want to let the world go back to normal when destroying that normal forever was the whole point of what was happening? House arrest, closing businesses and schools through lockdown, (un)social distancing and masks all followed the Ferguson fantasy models. Again as I predicted (these people are so predictable) when the 'vaccine' arrived we were told that house arrest, lockdown, (un)social distancing and masks would still have to continue. I will deal with the masks in the next chapter because they are of fundamental importance.

Where's the 'pandemic'?

Any mildly in-depth assessment of the figures revealed what was really going on. Cult-funded and controlled organisations still have genuine people working within them such is the number involved. So it is with Genevieve Briand, assistant program director of the Applied Economics master's degree program at Johns Hopkins

University. She analysed the impact that 'Covid-19' had on deaths from *all* causes in the United States using official data from the CDC for the period from early February to early September, 2020. She found that allegedly 'Covid' *related*-deaths exceeded those from heart disease which she found strange with heart disease always the biggest cause of fatalities. Her research became even more significant when she noted the sudden decline in 2020 of *all* non-'Covid' deaths: 'This trend is completely contrary to the pattern observed in all previous years … the total decrease in deaths by other causes almost exactly equals the increase in deaths by Covid-19.' This was such a game, set and match in terms of what was happening that Johns Hopkins University deleted the article on the grounds that it 'was being used to support false and dangerous inaccuracies about the impact of the pandemic'. No – because it exposed the scam from official CDC figures and this was confirmed when those figures were published in January, 2021. Here we can see the effect of people dying from heart attacks, cancer, road accidents and gunshot wounds – *anything* – having 'Covid-19' on the death certificate along with those diagnosed from 'symptoms' who had even not tested positive with a test not testing for the 'virus'. I am not kidding with the gunshot wounds, by the way. Brenda Bock, coroner in Grand County, Colorado, revealed that two gunshot victims tested positive for the 'virus' within the previous 30 days and were therefore classified as 'Covid deaths'. Bock said: 'These two people had tested positive for Covid, but that's not what killed them. A gunshot wound is what killed them.' She said she had not even finished her investigation when the state listed the gunshot victims as deaths due to the 'virus'. The death and case figures for 'Covid-19' are an absolute joke and yet they are repeated like parrots by the media, politicians and alleged medical 'experts'. The official Cult narrative is the only show in town.

Genevieve Briand found that deaths from all causes were not exceptional in 2020 compared with previous years and a Spanish magazine published figures that said the same about Spain which was a 'Covid' propaganda hotspot at one point. *Discovery Salud*, a

health and medicine magazine, quoted government figures which showed how 17,000 *fewer* people died in Spain in 2020 than in 2019 and more than 26,000 fewer than in 2018. The age-standardised mortality rate for England and Wales when age distribution is taken into account was significantly lower in 2020 than the 1970s, 80s and 90s, and was only the ninth highest since 2000. Where is the 'pandemic'?

Post mortems and autopsies virtually disappeared for 'Covid' deaths amid claims that 'virus-infected' bodily fluids posed a risk to those carrying out the autopsy. This was rejected by renowned German pathologist and forensic doctor Klaus Püschel who said that he and his staff had by then done 150 autopsies on 'Covid' patients with no problems at all. He said they were needed to know why some 'Covid' patients suffered blood clots and not severe respiratory infections. The 'virus' is, after all, called SARS or 'severe acute respiratory syndrome'. I highlighted in the spring of 2020 this phenomenon and quoted New York intensive care doctor Cameron Kyle-Sidell who posted a soon deleted YouTube video to say that they had been told to prepare to treat an infectious disease called 'Covid-19', but that was not what they were dealing with. Instead he likened the lung condition of the most severely ill patients to what you would expect with cabin depressurisation in a plane at 30,000 feet or someone dropped on the top of Everest without oxygen or acclimatisation. I have never said this is not happening to a small minority of alleged 'Covid' patients – I am saying this is not caused by a phantom 'contagious virus'. Indeed Kyle-Sidell said that 'Covid-19' was not the disease they were told was coming their way. 'We are operating under a medical paradigm that is untrue,' he said, and he believed they were treating the wrong disease: 'These people are being slowly starved of oxygen.' Patients would take off their oxygen masks in a state of fear and stress and while they were blue in the face on the brink of death. They did not look like patients dying of pneumonia. You can see why they don't want autopsies when their virus doesn't exist and there is another condition in some people that they don't wish to be uncovered. I should add here that

the 5G system of millimetre waves was being rapidly introduced around the world in 2020 and even more so now as they fire 5G at the Earth from satellites. At 60 gigahertz within the 5G range that frequency interacts with the oxygen molecule and stops people breathing in sufficient oxygen to be absorbed into the bloodstream. They are installing 5G in schools and hospitals. The world is not mad or anything. 5G can cause major changes to the lungs and blood as I detail in *The Answer* and these consequences are labelled 'Covid-19', the alleged symptoms of which can be caused by 5G and other electromagnetic frequencies as cells respond to radiation poisoning.

The 'Covid death' scam

Dr Scott Jensen, a Minnesota state senator and medical doctor, exposed 'Covid' Medicare payment incentives to hospitals and death certificate manipulation. He said he was sent a seven-page document by the US Department of Health 'coaching' him on how to fill out death certificates which had never happened before. The document said that he didn't need to have a laboratory test for 'Covid-19' to put that on the death certificate and that shocked him when death certificates are supposed to be about facts. Jensen described how doctors had been 'encouraged, if not pressured' to make a diagnosis of 'Covid-19' if they thought it was probable or *'presumed*'. No positive test was necessary – not that this would have mattered anyway. He said doctors were told to diagnose 'Covid' by symptoms when these were the same as colds, allergies, other respiratory problems, and certainly with influenza which 'disappeared' in the 'Covid' era. A common sniffle was enough to get the dreaded verdict. Ontario authorities decreed that a single care home resident with *one* symptom from a long list must lead to the isolation of the entire home. Other courageous doctors like Jensen made the same point about death figure manipulation and how deaths by other causes were falling while 'Covid-19 deaths' were rising at the same rate due to re-diagnosis. Their videos rarely survive long on YouTube with its Cult-supporting algorithms courtesy of CEO Susan Wojcicki and her bosses at Google. Figure-tampering was so glaring

and ubiquitous that even officials were letting it slip or outright saying it. UK chief scientific adviser Patrick Vallance said on one occasion that 'Covid' on the death certificate doesn't mean 'Covid' was the cause of death (so why the hell is it there?) and we had the rare sight of a BBC reporter telling the truth when she said: 'Someone could be successfully treated for Covid, in say April, discharged, and then in June, get run over by a bus and die … That person would still be counted as a Covid death in England.' Yet the BBC and the rest of the world media went on repeating the case and death figures as if they were real. Illinois Public Health Director Dr Ngozi Ezike revealed the deceit while her bosses must have been clenching their buttocks:

> If you were in a hospice and given a few weeks to live and you were then found to have Covid that would be counted as a Covid death. [There might be] a clear alternate cause, but it is still listed as a Covid death. So everyone listed as a Covid death doesn't mean that was the cause of the death, but that they had Covid at the time of death.

Yes, a 'Covid virus' never shown to exist and tested for with a test not testing for the 'virus'. In the first period of the pandemic hoax through the spring of 2020 the process began of designating almost everything a 'Covid' death and this has continued ever since. I sat in a restaurant one night listening to a loud conversation on the next table where a family was discussing in bewilderment how a relative who had no symptoms of 'Covid', and had died of a long-term problem, could have been diagnosed a death by the 'virus'. I could understand their bewilderment. If they read this book they will know why this medical fraud has been perpetrated the world over.

Some media truth shock

The media ignored the evidence of death certificate fraud until eventually one columnist did speak out when she saw it first-hand. Bel Mooney is a long-time national newspaper journalist in Britain currently working for the *Daily Mail*. Her article on February 19th, 2021, carried this headline: 'My dad Ted passed three Covid tests

and died of a chronic illness yet he's officially one of Britain's 120,000 victims of the virus and is far from alone ... so how many more are there?' She told how her 99-year-old father was in a care home with a long-standing chronic obstructive pulmonary disease and vascular dementia. Maybe, but he was still aware enough to tell her from the start that there was no 'virus' and he refused the 'vaccine' for that reason. His death was not unexpected given his chronic health problems and Mooney said she was shocked to find that 'Covid-19' was declared the cause of death on his death certificate. She said this was a 'bizarre and unacceptable untruth' for a man with long-time health problems who had tested negative twice at the home for the 'virus'. I was also shocked by this story although not by what she said. I had been highlighting the death certificate manipulation for ten months. It was the confirmation that a professional full-time journalist only realised this was going on when it affected her directly and neither did she know that whether her dad tested positive or negative was irrelevant with the test not testing for the 'virus'. Where had she been? She said she did not believe in 'conspiracy theories' without knowing I'm sure that this and 'conspiracy theorists' were terms put into widespread circulation by the CIA in the 1960s to discredit those who did not accept the ridiculous official story of the Kennedy assassination. A blanket statement of 'I don't believe in conspiracy theories' is always bizarre. The dictionary definition of the term alone means the world is drowning in conspiracies. What she said was even more daft when her dad had just been affected by the 'Covid' conspiracy. Why else does she think that 'Covid-19' was going on the death certificates of people who died of something else?

To be fair once she saw from personal experience what was happening she didn't mince words. Mooney was called by the care home on the morning of February 9th to be told her father had died in his sleep. When she asked for the official cause of death what came back was 'Covid-19'. Mooney challenged this and was told there had been deaths from Covid on the dementia floor (confirmed by a test not testing for the 'virus') so they considered it 'reasonable

to assume'. 'But doctor,' Mooney rightly protested, 'an assumption isn't a diagnosis.' She said she didn't blame the perfectly decent and sympathetic doctor – 'he was just doing his job'. Sorry, but that's *bullshit*. He wasn't doing his job at all. He was putting a false cause of death on the death certificate and that is a criminal offence for which he should be brought to account and the same with the millions of doctors worldwide who have done the same. They were not doing their job they were following orders and that must not wash at new Nuremberg trials any more than it did at the first ones. Mooney's doctor was 'assuming' (presuming) as he was told to, but 'just following orders' makes no difference to his actions. A doctor's job is to serve the patient and the truth, not follow orders, but that's what they have done all over the world and played a central part in making the 'Covid' hoax possible with all its catastrophic consequences for humanity. Shame on them and they must answer for their actions. Mooney said her disquiet worsened when she registered her father's death by telephone and was told by the registrar there had been very many other cases like hers where 'the deceased' had not tested positive for 'Covid' yet it was recorded as the cause of death. The test may not matter, but those involved at their level *think* it matters and it shows a callous disregard for accurate diagnosis. The pressure to do this is coming from the top of the national 'health' pyramids which in turn obey the World Health Organization which obeys Gates and the Cult. Mooney said the registrar agreed that this must distort the national figures adding that 'the strangest thing is that every winter we record countless deaths from flu, and this winter there have been none. Not one!' She asked if the registrar thought deaths from flu were being misdiagnosed and lumped together with 'Covid' deaths. The answer was a 'puzzled yes'. Mooney said that the funeral director said the same about 'Covid' deaths which had nothing to do with 'Covid'. They had lost count of the number of families upset by this and other funeral companies in different countries have had the same experience. Mooney wrote:

The nightly shroud-waving and shocking close-ups of pain imposed on us by the TV news bewildered and terrified the population into eager compliance with lockdowns. We were invited to 'save the NHS' and to grieve for strangers – the real-life loved ones behind those shocking death counts. Why would the public imagine what I now fear, namely that the way Covid-19 death statistics are compiled might make the numbers seem greater than they are?

Oh, just a little bit – like 100 percent.

Do the maths

Mooney asked why a country would wish to skew its mortality figures by wrongly certifying deaths? What had been going on? Well, if you don't believe in conspiracies you will never find the answer which is that *it's a conspiracy*. She did, however, describe what she had discovered as a 'national scandal'. In reality it's a global scandal and happening everywhere. Pillars of this conspiracy were all put into place before the button was pressed with the Drosten PCR protocol and high amplifications to produce the cases and death certificate changes to secure illusory 'Covid' deaths. Mooney notes that normally two doctors were needed to certify a death, with one having to know the patient, and how the rules were changed in the spring of 2020 to allow one doctor to do this. In the same period 'Covid deaths' were decreed to be all cases where Covid-19 was put on the death certificate even without a positive test or any symptoms. Mooney asked: 'How many of the 30,851 (as of January 15) care home resident deaths with Covid-19 on the certificate (32.4 per cent of all deaths so far) were based on an assumption, like that of my father? And what has that done to our national psyche?'All of them is the answer to the first question and it has devastated and dismantled the national psyche, actually the global psyche, on a colossal scale. In the UK case and death data is compiled by organisations like Public Health England (PHE) and the Office for National Statistics (ONS). Mooney highlights the insane policy of counting a death from any cause as 'Covid-19' if this happens within 28 days of a positive test (with a test not testing for the 'virus') and she points out that ONS statistics reflect deaths 'involving Covid' 'or due to Covid' which meant in practice any

death where 'Covid-19' was mentioned on the death certificate. She described the consequences of this fraud:

Most people will accept the narrative they are fed, so panicky governments here and in Europe witnessed the harsh measures enacted in totalitarian China and jumped into lockdown. Headlines about Covid deaths tolled like the knell that would bring doomsday to us all. Fear stalked our empty streets. Politicians parroted the frankly ridiculous aim of 'zero Covid' and shut down the economy, while most British people agreed that lockdown was essential and (astonishingly to me, as a patriotic Brit) even wanted more restrictions.

For what? Lies on death certificates? Never mind the grim toll of lives ruined, suicides, schools closed, rising inequality, depression, cancelled hospital treatments, cancer patients in a torture of waiting, poverty, economic devastation, loneliness, families kept apart, and so on. How many lives have been lost as a direct result of lockdown?

She said that we could join in a national chorus of shock and horror at reaching the 120,000 death toll which was surely certain to have been totally skewed all along, but what about the human cost of lockdown justified by these 'death figures'? *The British Medical Journal* had reported a 1,493 percent increase in cases of children taken to Great Ormond Street Hospital with abusive head injuries alone and then there was the effect on families:

Perhaps the most shocking thing about all this is that families have been kept apart – and obeyed the most irrational, changing rules at the whim of government – because they believed in the statistics. They succumbed to fear, which his generation rejected in that war fought for freedom. Dad (God rest his soul) would be angry. And so am I.

Another theme to watch is that in the winter months when there are more deaths from all causes they focus on 'Covid' deaths and in the summer when the British Lung Foundation says respiratory disease plummets by 80 percent they rage on about 'cases'. Either way fascism on population is always the answer.

Nazi eugenics in the 21st century

Elderly people in care homes have been isolated from their families month after lonely month with no contact with relatives and grandchildren who were banned from seeing them. We were told

that lockdown fascism was to 'protect the vulnerable' like elderly people. At the same time Do Not Resuscitate (DNR) orders were placed on their medical files so that if they needed resuscitation it wasn't done and 'Covid-19' went on their death certificates. Old people were not being 'protected' they were being culled – murdered in truth. DNR orders were being decreed for disabled and young people with learning difficulties or psychological problems. The UK Care Quality Commission, a non-departmental body of the Department of Health and Social Care, found that 34 percent of those working in health and social care were pressured into placing 'do not attempt cardiopulmonary resuscitation' orders on 'Covid' patients who suffered from disabilities and learning difficulties without involving the patient or their families in the decision. UK judges ruled that an elderly woman with dementia should have the DNA-manipulating 'Covid vaccine' against her son's wishes and that a man with severe learning difficulties should have the jab despite his family's objections. Never mind that many had already died. The judiciary always supports doctors and government in fascist dictatorships. They wouldn't dare do otherwise. A horrific video was posted showing fascist officers from Los Angeles police forcibly giving the 'Covid' shot to women with special needs who were screaming that they didn't want it. The same fascists are seen giving the jab to a sleeping elderly woman in a care home. This is straight out of the Nazi playbook. Hitler's Nazis committed mass murder of the mentally ill and physically disabled throughout Germany and occupied territories in the programme that became known as Aktion T4, or just T4. Sabbatian-controlled Hitler and his grotesque crazies set out to kill those they considered useless and unnecessary. The Reich Committee for the Scientific Registering of Hereditary and Congenital Illnesses registered the births of babies identified by physicians to have 'defects'. By 1941 alone more than 5,000 children were murdered by the state and it is estimated that in total the number of innocent people killed in Aktion T4 was between 275,000 and 300,000. Parents were told their children had been sent away for 'special treatment' never to return. It is rather pathetic to see claims about plans for new extermination camps being dismissed today

when the same force behind current events did precisely that 80 years ago. Margaret Sanger was a Cult operative who used 'birth control' to sanitise her programme of eugenics. Organisations she founded became what is now Planned Parenthood. Sanger proposed that 'the whole dysgenic population would have its choice of segregation or sterilization'. These included epileptics, 'feeble-minded', and prostitutes. Sanger opposed charity because it perpetuated 'human waste'. She reveals the Cult mentality and if anyone thinks that extermination camps are a 'conspiracy theory' their naivety is touching if breathtakingly stupid.

If you don't believe that doctors can act with callous disregard for their patients it is worth considering that doctors and medical staff agreed to put government-decreed DNR orders on medical files and do nothing when resuscitation is called for. I don't know what you call such people in your house. In mine they are Nazis from the Josef Mengele School of Medicine. Phenomenal numbers of old people have died worldwide from the effects of lockdown, depression, lack of treatment, the 'vaccine' (more later) and losing the will to live. A common response at the start of the manufactured pandemic was to remove old people from hospital beds and transfer them to nursing homes. The decision would result in a mass cull of elderly people in those homes through lack of treatment – *not* 'Covid'. Care home whistleblowers have told how once the 'Covid' era began doctors would not come to their homes to treat patients and they were begging for drugs like antibiotics that often never came. The most infamous example was ordered by New York governor Andrew Cuomo, brother of a moronic CNN host, who amazingly was given an Emmy Award for his handling of the 'Covid crisis' by the ridiculous Wokers that hand them out. Just how ridiculous could be seen in February, 2021, when a Department of Justice and FBI investigation began into how thousands of old people in New York died in nursing homes after being discharged from hospital to make way for 'Covid' patients on Cuomo's say-so – and how he and his staff covered up these facts. This couldn't have happened to a nicer psychopath. Even then there was a 'Covid' spin. Reports said that

thousands of old people who tested positive for 'Covid' in hospital were transferred to nursing homes to both die of 'Covid' and transmit it to others. No – they were in hospital because they were ill and the fact that they tested positive with a test not testing for the 'virus' is irrelevant. They were ill often with respiratory diseases ubiquitous in old people near the end of their lives. Their transfer out of hospital meant that their treatment stopped and many would go on to die.

They're old. Who gives a damn?

I have exposed in the books for decades the Cult plan to cull the world's old people and even to introduce at some point what they call a 'demise pill' which at a certain age everyone would take and be out of here by law. In March, 2021, Spain legalised euthanasia and assisted suicide following the Netherlands, Belgium, Luxembourg and Canada on the Tiptoe to the demise pill. Treatment of old people by many 'care' homes has been a disgrace in the 'Covid' era. There are many, many, caring staff – I know some. There have, however, been legions of stories about callous treatment of old people and their families. Police were called when families came to take their loved ones home in the light of isolation that was killing them. They became prisoners of the state. Care home residents in insane, fascist Ontario, Canada, were not allowed to leave their *room* once the 'Covid' hoax began. UK staff have even wheeled elderly people away from windows where family members were talking with them. Oriana Criscuolo from Stockport in the English North West dropped off some things for her 80-year-old father who has Parkinson's disease and dementia and she wanted to wave to him through a ground-floor window. She was told that was 'illegal'. When she went anyway they closed the curtains in the middle of the day. Oriana said:

> It's just unbelievable. I cannot understand how care home staff – people who are being paid to care – have become so uncaring. Their behaviour is inhumane and cruel. It's beyond belief.

She was right and this was not a one-off. What a way to end your life in such loveless circumstances. UK registered nurse Nicky Millen, a proper old school nurse for 40 years, said that when she started her career care was based on dignity, choice, compassion and empathy. Now she said 'the things that are important to me have gone out of the window.' She was appalled that people were dying without their loved ones and saying goodbye on iPads. Nicky described how a distressed 89-year-old lady stroked her face and asked her 'how many paracetamol would it take to finish me off'. Life was no longer worth living while not seeing her family. Nicky said she was humiliated in front of the ward staff and patients for letting the lady stroke her face and giving her a cuddle. Such is the dehumanisation that the 'Covid' hoax has brought to the surface. Nicky worked in care homes where patients told her they were being held prisoner. 'I want to live until I die', one said to her. 'I had a lady in tears because she hadn't seen her great-grandson.' Nicky was compassionate old school meeting psychopathic New Normal. She also said she had worked on a 'Covid' ward with no 'Covid' patients. Jewish writer Shai Held wrote an article in March, 2020, which was headlined 'The Staggering, Heartless Cruelty Toward the Elderly'. What he described was happening from the earliest days of lockdown. He said 'the elderly' were considered a group and not unique individuals (the way of the Woke). Shai Held said:

Notice how the all-too-familiar rhetoric of dehumanization works: 'The elderly' are bunched together as a faceless mass, all of them considered culprits and thus effectively deserving of the suffering the pandemic will inflict upon them. Lost entirely is the fact that the elderly are individual human beings, each with a distinctive face and voice, each with hopes and dreams, memories and regrets, friendships and marriages, loves lost and loves sustained.

'The elderly' have become another dehumanised group for which anything goes and for many that has resulted in cold disregard for their rights and their life. The distinctive face that Held talks about is designed to be deleted by masks until everyone is part of a faceless mass.

‘War-zone’ hospitals myth

Again and again medical professionals have told me what was really going on and how hospitals ‘overrun like war zones’ according to the media were virtually empty. The mantra from medical whistleblowers was please don’t use my name or my career is over. Citizen journalists around the world sneaked into hospitals to film evidence exposing the ‘war-zone’ lie. They really *were* largely empty with closed wards and operating theatres. I met a hospital worker in my town on the Isle of Wight during the first lockdown in 2020 who said the only island hospital had never been so quiet. Lockdown was justified by the psychopaths to stop hospitals being overrun. At the same time that the island hospital was near-empty the military arrived here to provide *extra beds*. It was all propaganda to ramp up the fear to ensure compliance with fascism as were never-used temporary hospitals with thousands of beds known as Nightingales and never-used make-shift mortuaries opened by the criminal UK government. A man who helped to install those extra island beds attributed to the army said they were never used and the hospital was empty. Doctors and nurses ‘stood around talking or on their phones, wandering down to us to see what we were doing’. There were no masks or social distancing. He accused the useless local island paper, the *County Press*, of ‘pumping the fear as if our hospital was overrun and we only have one so it should have been’. He described ambulances parked up with crews outside in deck chairs. When his brother called an ambulance he was told there was a two-hour backlog which he called ‘bullshit’. An old lady on the island fell ‘and was in a bad way’, but a caller who rang for an ambulance was told the situation wasn’t urgent enough. Ambulance stations were working under capacity while people would hear ambulances with sirens blaring driving through the streets. When those living near the stations realised what was going on they would follow them as they left, circulated around an urban area with the sirens going, and then came back without stopping. All this was to increase levels of fear and the same goes for the ‘ventilator shortage crisis’ that cost tens of millions for hastily produced ventilators never to be used.

Ambulance crews that agreed to be exploited in this way for fear propaganda might find themselves a mirror. I wish them well with that. Empty hospitals were the obvious consequence of treatment and diagnoses of non-'Covid' conditions cancelled and those involved handed a death sentence. People have been dying at home from undiagnosed and untreated cancer, heart disease and other life-threatening conditions to allow empty hospitals to deal with a 'pandemic' that wasn't happening.

Death of the innocent

'War-zones' have been laying off nursing staff, even doctors where they can. There was no work for them. Lockdown was justified by saving lives and protecting the vulnerable they were actually killing with DNR orders and preventing empty hospitals being 'overrun'. In Britain the mantra of stay at home to 'save the NHS' was everywhere and across the world the same story was being sold when it was all lies. Two California doctors, Dan Erickson and Artin Massihi at Accelerated Urgent Care in Bakersfield, held a news conference in April, 2020, to say that intensive care units in California were 'empty, essentially', with hospitals shutting floors, not treating patients and laying off doctors. The California health system was working at minimum capacity 'getting rid of doctors because we just don't have the volume'. They said that people with conditions such as heart disease and cancer were not coming to hospital out of fear of 'Covid-19'. Their video was deleted by Susan Wojcicki's Cult-owned YouTube after reaching five million views. Florida governor Ron Desantis, who rejected the severe lockdowns of other states and is being targeted for doing so, said that in March, 2020, every US governor was given models claiming they would run out of hospital beds in days. That was never going to happen and the 'modellers' knew it. Deceit can be found at every level of the system. Urgent children's operations were cancelled including fracture repairs and biopsies to spot cancer. Eric Nicholls, a consultant paediatrician, said 'this is obviously concerning and we need to return to normal operating and to increase capacity as soon as possible'. Psychopaths

in power were rather less concerned *because* they are psychopaths. Deletion of urgent care and diagnosis has been happening all over the world and how many kids and others have died as a result of the actions of these cold and heartless lunatics dictating 'health' policy? The number must be stratospheric. Richard Sullivan, professor of cancer and global health at King's College London, said people feared 'Covid' more than cancer such was the campaign of fear. 'Years of lost life will be quite dramatic', Sullivan said, with 'a huge amount of avoidable mortality'. Sarah Woolnough, executive director for policy at Cancer Research UK, said there had been a 75 percent drop in urgent referrals to hospitals by family doctors of people with suspected cancer. Sullivan said that 'a lot of services have had to scale back – we've seen a dramatic decrease in the amount of elective cancer surgery'. Lockdown deaths worldwide has been absolutely fantastic with the *New York Post* reporting how data confirmed that 'lockdowns end more lives than they save':

> There was a sharp decline in visits to emergency rooms and an increase in fatal heart attacks because patients didn't receive prompt treatment. Many fewer people were screened for cancer. Social isolation contributed to excess deaths from dementia and Alzheimer's.
>
> Researchers predicted that the social and economic upheaval would lead to tens of thousands of "deaths of despair" from drug overdoses, alcoholism and suicide. As unemployment surged and mental-health and substance-abuse treatment programs were interrupted, the reported levels of anxiety, depression and suicidal thoughts increased dramatically, as did alcohol sales and fatal drug overdoses.

This has been happening while nurses and other staff had so much time on their hands in the 'war-zones' that Tic-Tok dancing videos began appearing across the Internet with medical staff dancing around in empty wards and corridors as people died at home from causes that would normally have been treated in hospital.

Mentions in dispatches

One brave and truth-committed whistleblower was Louise Hampton, a call handler with the UK NHS who made a viral Internet video saying she had done 'fuck all' during the 'pandemic'

which was 'a load of bollocks'. She said that 'Covid-19' was rebranded flu and of course she lost her job. This is what happens in the medical and endless other professions now when you tell the truth. Louise filmed inside 'war-zone' accident and emergency departments to show they were empty and I mean *empty* as in no one there. The mainstream media could have done the same and blown the gaff on the whole conspiracy. They haven't to their eternal shame. Not that most 'journalists' seem capable of manifesting shame as with the psychopaths they slavishly repeat without question. The relative few who were admitted with serious health problems were left to die alone with no loved ones allowed to see them because of 'Covid' rules and they included kids dying without the comfort of mum and dad at their bedside while the evil behind this couldn't give a damn. It was all good fun to them. A Scottish NHS staff nurse publicly quit in the spring of 2021 saying: 'I can no longer be part of the lies and the corruption by the government.' She said hospitals 'aren't full, the beds aren't full, beds have been shut, wards have been shut'. Hospitals were never busy throughout 'Covid'. The staff nurse said that Nicola Sturgeon, tragically the leader of the Scottish government, was on television saying save the hospitals and the NHS – 'but the beds are empty' and 'we've not seen flu, we always see flu every year'. She wrote to government and spoke with her union Unison (the unions are Cult-compromised and *useless*, but nothing changed. Many of her colleagues were scared of losing their jobs if they spoke out as they wanted to. She said nursing staff were being affected by wearing masks all day and 'my head is splitting every shift from wearing a mask'. The NHS is part of the fascist tyranny and must be dismantled so we can start again with human beings in charge. (Ironically, hospitals were reported to be busier again when official 'Covid' cases *fell* in spring/summer of 2021 and many other conditions required treatment at the same time as *the fake vaccine rollout*.)

I will cover the 'Covid vaccine' scam in detail later, but it is another indicator of the sickening disregard for human life that I am highlighting here. The DNA-manipulating concoctions do not fulfil

the definition of a 'vaccine', have never been used on humans before and were given only emergency approval because trials were not completed and they continued using the unknowing public. The result was what a NHS senior nurse with responsibility for 'vaccine' procedure said was 'genocide'. She said the 'vaccines' were not 'vaccines'. They had not been shown to be safe and claims about their effectiveness by drug companies were 'poetic licence'. She described what was happening as a 'horrid act of human annihilation'. The nurse said that management had instigated a policy of not providing a Patient Information Leaflet (PIL) before people were 'vaccinated' even though health care professionals are supposed to do this according to protocol. Patients should also be told that they are taking part in an ongoing clinical trial. Her challenges to what is happening had seen her excluded from meetings and ridiculed in others. She said she was told to 'watch my step … or I would find myself surplus to requirements'. The nurse, who spoke anonymously in fear of her career, said she asked her NHS manager why he/she was content with taking part in genocide against those having the 'vaccines'. The reply was that everyone had to play their part and to 'put up, shut up, and get it done'. Government was 'leaning heavily' on NHS management which was clearly leaning heavily on staff. This is how the global 'medical' hierarchy operates and it starts with the Cult and its World Health Organization.

She told the story of a doctor who had the Pfizer jab and when questioned had no idea what was in it. The doctor had never read the literature. We have to stop treating doctors as intellectual giants when so many are moral and medical pygmies. The doctor did not even know that the 'vaccines' were not fully approved or that their trials were ongoing. They were, however, asking their patients if they minded taking part in follow-ups for research purposes – yes, the *ongoing clinical trial*. The nurse said the doctor's ignorance was not rare and she had spoken to a hospital consultant who had the jab without any idea of the background or that the 'trials' had not been completed. Nurses and pharmacists had shown the same ignorance.

'My NHS colleagues have forsaken their duty of care, broken their code of conduct – Hippocratic Oath – and have been brainwashed just the same as the majority of the UK public through propaganda …' She said she had not been able to recruit a single NHS colleague, doctor, nurse or pharmacist to stand with her and speak out. Her union had refused to help. She said that if the genocide came to light she would not hesitate to give evidence at a Nuremberg-type trial against those in power who could have affected the outcomes but didn't.

And all for what?

To put the nonsense into perspective let's say the 'virus' does exist and let's go completely crazy and accept that the official manipulated figures for cases and deaths are accurate. *Even then* a study by Stanford University epidemiologist Dr John Ioannidis published on the World Health Organization website produced an average infection to fatality rate of … *0.23 percent!* Ioannidis said: 'If one could sample equally from all locations globally, the median infection fatality rate might even be substantially lower than the 0.23% observed in my analysis.' For healthy people under 70 it was … *0.05 percent*! This compares with the 3.4 percent claimed by the Cult-owned World Health Organization when the hoax was first played and maximum fear needed to be generated. An updated Stanford study in April, 2021, put the 'infection' to 'fatality' rate at just 0.15 percent. Another team of scientists led by Megan O'Driscoll and Henrik Salje studied data from 45 countries and published their findings on the Nature website. For children and young people the figure is so small it virtually does not register although authorities will be hyping dangers to the young when they introduce DNA-manipulating 'vaccines' for children. The O'Driscoll study produced an average infection-fatality figure of 0.003 for children from birth to four; 0.001 for 5 to 14; 0.003 for 15 to 19; and it was still only 0.456 up to 64. To claim that children must be 'vaccinated' to protect them from 'Covid' is an obvious lie and so there must be another reason and there is. What's more the average age of a 'Covid' death is akin

to the average age that people die in general. The average age of death in England is about 80 for men and 83 for women. The average age of death from alleged 'Covid' is between 82 and 83. California doctors, Dan Erickson and Artin Massihi, said at their April media conference that projection models of millions of deaths had been 'woefully inaccurate'. They produced detailed figures showing that Californians had a 0.03 chance of dying from 'Covid' based on the number of people who tested positive (with a test not testing for the 'virus'). Erickson said there was a 0.1 percent chance of dying from 'Covid' in the *state* of New York, not just the city, and a 0.05 percent chance in Spain, a centre of 'Covid-19' hysteria at one stage. The Stanford studies supported the doctors' data with fatality rate estimates of 0.23 and 0.15 percent. How close are these figures to my estimate of *zero*? Death-rate figures claimed by the World Health Organization at the start of the hoax were some 15 times higher. The California doctors said there was no justification for lockdowns and the economic devastation they caused. Everything they had ever learned about quarantine was that you quarantine the *sick* and not the healthy. They had never seen this before and it made no medical sense.

Why in the in the light of all this would governments and medical systems the world over say that billions must go under house arrest; lose their livelihood; in many cases lose their mind, their health and their life; force people to wear masks dangerous to health and psychology; make human interaction and even family interaction a criminal offence; ban travel; close restaurants, bars, watching live sport, concerts, theatre, and any activity involving human togetherness and discourse; and closing schools to isolate children from their friends and cause many to commit suicide in acts of hopelessness and despair? The California doctors said lockdown consequences included increased child abuse, partner abuse, alcoholism, depression, and other impacts they were seeing every day. Who would do that to the entire human race if not mentally-ill psychopaths of almost unimaginable extremes like Bill Gates? We must face the reality of what we are dealing with and come out of

denial. Fascism and tyranny are made possible only by the target population submitting and acquiescing to fascism and tyranny. The whole of human history shows that to be true. Most people naively and unquestioning believed what they were told about a 'deadly virus' and meekly and weakly submitted to house arrest. Those who didn't believe it – at least in total – still submitted in fear of the consequences of not doing so. For the rest who wouldn't submit draconian fines have been imposed, brutal policing by psychopaths *for* psychopaths, and condemnation from the meek and weak who condemn the Pushbackers on behalf of the very force that has them, too, in its gunsights. 'Pathetic' does not even begin to suffice. Britain's brainless 'Health' Secretary Matt Hancock warned anyone lying to border officials about returning from a list of 'hotspot' countries could face a jail sentence of up to ten years which is more than for racially-aggravated assault, incest and attempting to have sex with a child under 13. Hancock is a lunatic, but he has the state apparatus behind him in a Cult-led chain reaction and the same with UK 'Vaccine Minister' Nadhim Zahawi, a prominent member of the mega-Cult secret society, Le Cercle, which featured in my earlier books. The Cult enforces its will on governments and medical systems; government and medical systems enforce their will on business and police; business enforces its will on staff who enforce it on customers; police enforce the will of the Cult on the population and play their essential part in creating a world of fascist control that their own children and grandchildren will have to live in their entire lives. It is a hierarchical pyramid of imposition and acquiescence and, yes indeedy, of clinical insanity.

Does anyone bright enough to read this book have to ask what the answer is? I think not, but I will reveal it anyway in the fewest of syllables: Tell the psychos and their moronic lackeys to fuck off and let's get on with our lives. We are many – They are few.

CHAPTER SEVEN

War on your mind

One believes things because one has been conditioned to believe them
Aldous Huxley, *Brave New World*

I have described the 'Covid' hoax as a 'Psyop' and that is true in every sense and on every level in accordance with the definition of that term which is psychological warfare. Break down the 'Covid pandemic' to the foundation themes and it is psychological warfare on the human individual and collective mind.

The same can be said for the entire human belief system involving every subject you can imagine. Huxley was right in his contention that people believe what they are conditioned to believe and this comes from the repetition throughout their lives of the same falsehoods. They spew from government, corporations, media and endless streams of 'experts' telling you what the Cult wants you to believe and often believing it themselves (although *far* from always). 'Experts' are rewarded with 'prestigious' jobs and titles and as agents of perceptual programming with regular access to the media. The Cult has to control the narrative – control *information* – or they lose control of the vital, crucial, without-which-they-cannot-prevail public perception of reality. The foundation of that control today is the Internet made possible by the Defense Advanced Research Projects Agency (DARPA), the incredibly sinister technological arm of the Pentagon. The Internet is the result of military technology.

DARPA openly brags about establishing the Internet which has been a long-term project to lasso the minds of the global population. I have said for decades the plan is to control information to such an extreme that eventually no one would see or hear anything that the Cult does not approve. We are closing in on that end with ferocious censorship since the 'Covid' hoax began and in my case it started back in the 1990s in terms of books and speaking venues. I had to create my own publishing company in 1995 precisely because no one else would publish my books even then. I think they're all still running.

Cult Internet

To secure total control of information they needed the Internet in which pre-programmed algorithms can seek out 'unclean' content for deletion and even stop it being posted in the first place. The Cult had to dismantle print and non-Internet broadcast media to ensure the transfer of information to the appropriate-named 'Web' – a critical expression of the *Cult* web. We've seen the ever-quickening demise of traditional media and control of what is left by a tiny number of corporations operating worldwide. Independent journalism in the mainstream is already dead and never was that more obvious than since the turn of 2020. The Cult wants all information communicated via the Internet to globally censor and allow the plug to be pulled any time. Lockdowns and forced isolation has meant that communication between people has been through electronic means and no longer through face-to-face discourse and discussion. Cult psychopaths have targeted the bars, restaurants, sport, venues and meeting places in general for this reason. None of this is by chance and it's to stop people gathering in any kind of privacy or number while being able to track and monitor all Internet communications and block them as necessary. Even private messages between individuals have been censored by these fascists that control Cult fronts like Facebook, Twitter, Google and YouTube which are all officially run by Sabbatian place-people and from the background by higher-level Sabbatian place people.

Facebook, Google, Amazon and their like were seed-funded and supported into existence with money-no-object infusions of funds either directly or indirectly from DARPA and CIA technology arm In-Q-Tel. The Cult plays the long game and prepares very carefully for big plays like 'Covid'. Amazon is another front in the psychological war and pretty much controls the global market in book sales and increasingly publishing. Amazon's limitless funds have deleted fantastic numbers of independent publishers to seize global domination on the way to deciding which books can be sold and circulated and which cannot. Moves in that direction are already happening. Amazon's leading light Jeff Bezos is the grandson of Lawrence Preston Gise who worked with DARPA predecessor ARPA. Amazon has big connections to the CIA and the Pentagon. The plan I have long described went like this:

1. Employ military technology to establish the Internet.

2. Sell the Internet as a place where people can freely communicate without censorship and allow that to happen until the Net becomes the central and irreversible pillar of human society. If the Internet had been highly censored from the start many would have rejected it.

3. Fund and manipulate major corporations into being to control the circulation of information on your Internet using cover stories about geeks in garages to explain how they came about. Give them unlimited funds to expand rapidly with no need to make a profit for years while non-Cult companies who need to balance the books cannot compete. You know that in these circumstances your Googles, YouTubes, Facebooks and Amazons are going to secure near monopolies by either crushing or buying up the opposition.

4. Allow freedom of expression on both the Internet and communication platforms to draw people in until the Internet is the central and irreversible pillar of human society and your communication corporations have reached a stage of near monopoly domination.

5. Then unleash your always-planned frenzy of censorship on the basis of 'where else are you going to go?' and continue to expand that until nothing remains that the Cult does not want its human targets to see.

The process was timed to hit the 'Covid' hoax to ensure the best chance possible of controlling the narrative which they knew they had to do at all costs. They were, after all, about to unleash a 'deadly virus' that didn't really exist. If you do that in an environment of free-flowing information and opinion you would be dead in the

water before you could say Gates is a psychopath. The network was in place through which the Cult-created-and-owned World Health Organization could dictate the 'Covid' narrative and response policy slavishly supported by Cult-owned Internet communication giants and mainstream media while those telling a different story were censored. Google, YouTube, Facebook and Twitter openly announced that they would do this. What else would we expect from Cult-owned operations like Facebook which former executives have confirmed set out to make the platform more addictive than cigarettes and coldly manipulates emotions of its users to sow division between people and groups and scramble the minds of the young? If Zuckerberg lives out the rest of his life without going to jail for crimes against humanity, and most emphatically against the young, it will be a travesty of justice. Still, no matter, cause and effect will catch up with him eventually and the same with Sergey Brin and Larry Page at Google with its CEO Sundar Pichai who fix the Google search results to promote Cult narratives and hide the opposition. Put the same key words into Google and other search engines like DuckDuckGo and you will see how different results can be. Wikipedia is another intensely biased 'encyclopaedia' which skews its content to the Cult agenda. YouTube links to Wikipedia's version of 'Covid' and 'climate change' on video pages in which experts in their field offer a different opinion (even that is increasingly rare with Wojcicki censorship). Into this 'Covid' silence-them network must be added government media censors, sorry 'regulators', such as Ofcom in the UK which imposed tyrannical restrictions on British broadcasters that had the effect of banning me from ever appearing. Just to debate with me about my evidence and views on 'Covid' would mean breaking the fascistic impositions of Ofcom and its CEO career government bureaucrat Melanie Dawes. Gutless British broadcasters tremble at the very thought of fascist Ofcom.

Psychos behind 'Covid'

The reason for the 'Covid' catastrophe in all its facets and forms can be seen by whom and what is driving the policies worldwide in such a coordinated way. Decisions are not being made to protect health, but to target psychology. The dominant group guiding and 'advising' government policy are not medical professionals. They are psychologists and behavioural scientists. Every major country has its own version of this phenomenon and I'll use the British example to show how it works. In many ways the British version has been affecting the wider world in the form of the huge behaviour manipulation network in the UK which operates in other countries. The network involves private companies, government, intelligence and military. The Cabinet Office is at the centre of the government 'Covid' Psyop and part-owns, with 'innovation charity' Nesta, the Behavioural Insights Team (BIT) which claims to be independent of government but patently isn't. The BIT was established in 2010 and its job is to manipulate the psyche of the population to acquiesce to government demands and so much more. It is also known as the 'Nudge Unit', a name inspired by the 2009 book by two ultra-Zionists, Cass Sunstein and Richard Thaler, called *Nudge: Improving Decisions About Health, Wealth, and Happiness*. The book, as with the Behavioural Insights Team, seeks to 'nudge' behaviour (manipulate it) to make the public follow patterns of action and perception that suit those in authority (the Cult). Sunstein is so skilled at this that he advises the World Health Organization and the UK Behavioural Insights Team and was Administrator of the White House Office of Information and Regulatory Affairs in the Obama administration. Biden appointed him to the Department of Homeland Security – another ultra-Zionist in the fold to oversee new immigration laws which is another policy the Cult wants to control. Sunstein is desperate to silence anyone exposing conspiracies and co-authored a 2008 report on the subject in which suggestions were offered to ban 'conspiracy theorizing' or impose 'some kind of tax, financial or otherwise, on those who disseminate such theories'. I guess a psychiatrist's chair is out of the question?

Sunstein's mate Richard Thaler, an 'academic affiliate' of the UK Behavioural Insights Team, is a proponent of 'behavioural economics' which is defined as the study of 'the effects of psychological, cognitive, emotional, cultural and social factors on the decisions of individuals and institutions'. Study the effects so they can be manipulated to be what you want them to be. Other leading names in the development of behavioural economics are ultra-Zionists Daniel Kahneman and Robert J. Shiller and they, with Thaler, won the Nobel Memorial Prize in Economic Sciences for their work in this field. The Behavioural Insights Team is operating at the heart of the UK government and has expanded globally through partnerships with several universities including Harvard, Oxford, Cambridge, University College London (UCL) and Pennsylvania. They claim to have 'trained' (reframed) 20,000 civil servants and run more than 750 projects involving 400 randomised controlled trials in dozens of countries' as another version of mind reframers Common Purpose. BIT works from its office in New York with cities and their agencies, as well as other partners, across the United States and Canada – this is a company part-owned by the British government Cabinet Office. An executive order by President Cult-servant Obama established a US Social and Behavioral Sciences Team in 2015. They all have the same reason for being and that's to brainwash the population directly and by brainwashing those in positions of authority.

'Covid' mind game

Another prime aspect of the UK mind-control network is the 'independent' [joke] Scientific Pandemic Insights Group on Behaviours (SPI-B) which 'provides behavioural science advice aimed at anticipating and helping people adhere to interventions that are recommended by medical or epidemiological experts'. That means manipulating public perception and behaviour to do whatever government tells them to do. It's disgusting and if they really want the public to be 'safe' this lot should all be under lock and key. According to the government website SPI-B consists of

'behavioural scientists, health and social psychologists, anthropologists and historians' and advises the Whitty-Vallance-led Scientific Advisory Group for Emergencies (SAGE) which in turn advises the government on 'the science' (it doesn't) and 'Covid' policy. When politicians say they are being guided by 'the science' this is the rabble in each country they are talking about and that 'science' is dominated by behaviour manipulators to enforce government fascism through public compliance. The Behaviour Insight Team is headed by psychologist David Solomon Halpern, a visiting professor at King's College London, and connects with a national and global web of other civilian and military organisations as the Cult moves towards its goal of fusing them into one fascistic whole in every country through its 'Fusion Doctrine'. The behaviour manipulation network involves, but is not confined to, the Foreign Office; National Security Council; government communications headquarters (GCHQ); MI5; MI6; the Cabinet Office-based Media Monitoring Unit; and the Rapid Response Unit which 'monitors digital trends to spot emerging issues; including misinformation and disinformation; and identifies the best way to respond'.

There is also the 77th Brigade of the UK military which operates like the notorious Israeli military's Unit 8200 in manipulating information and discussion on the Internet by posing as members of the public to promote the narrative and discredit those who challenge it. Here we have the military seeking to manipulate *domestic* public opinion while the Nazis in government are fine with that. Conservative Member of Parliament Tobias Ellwood, an advocate of lockdown and control through 'vaccine passports', is a Lieutenant Colonel reservist in the 77th Brigade which connects with the military operation jHub, the 'innovation centre' for the Ministry of Defence and Strategic Command. jHub has also been involved with the civilian National Health Service (NHS) in 'symptom tracing' the population. The NHS is a key part of this mind control network and produced a document in December, 2020, explaining to staff how to use psychological manipulation with different groups and ages to get them to have the DNA-manipulating 'Covid vaccine'

that's designed to cumulatively rewrite human genetics. The document, called 'Optimising Vaccination Roll Out – Do's and Dont's for all messaging, documents and "communications" in the widest sense', was published by NHS England and the NHS Improvement *Behaviour Change Unit* in partnership with Public Health England and Warwick Business School. I hear the mantra about 'save the NHS' and 'protect the NHS' when we need to scrap the NHS and start again. The current version is far too corrupt, far too anti-human and totally compromised by Cult operatives and their assets. UK government broadcast media censor Ofcom will connect into this web – as will the BBC with its tremendous Ofcom influence – to control what the public see and hear and dictate mass perception. Nuremberg trials must include personnel from all these organisations.

The fear factor

The 'Covid' hoax has led to the creation of the UK Cabinet Office-connected Joint Biosecurity Centre (JBC) which is officially described as providing 'expert advice on pandemics' using its independent [all Cult operations are 'independent'] analytical function to provide real-time analysis about infection outbreaks to identify and respond to outbreaks of Covid-19'. Another role is to advise the government on a response to spikes in infections – 'for example by closing schools or workplaces in local areas where infection levels have risen'. Put another way, promoting the Cult agenda. The Joint Biosecurity Centre is modelled on the Joint Terrorism Analysis Centre which analyses intelligence to set 'terrorism threat levels' and here again you see the fusion of civilian and military operations and intelligence that has led to military intelligence producing documents about 'vaccine hesitancy' and how it can be combated. Domestic civilian matters and opinions should not be the business of the military. The Joint Biosecurity Centre is headed by Tom Hurd, director general of the Office for Security and Counter-Terrorism from the establishment-to-its-fingertips Hurd family. His father is former Foreign Secretary Douglas Hurd. How coincidental that Tom

Hurd went to the elite Eton College and Oxford University with Boris Johnson. Imperial College with its ridiculous computer modeller Neil Ferguson will connect with this gigantic web that will itself interconnect with similar set-ups in other major and not so major countries. Compared with this Cult network the politicians, be they Boris Johnson, Donald Trump or Joe Biden, are bit-part players 'following the science'. The network of psychologists was on the 'Covid' case from the start with the aim of generating maximum fear of the 'virus' to ensure compliance by the population. A government behavioural science group known as SPI-B produced a paper in March, 2020, for discussion by the main government science advisory group known as SAGE. It was headed 'Options for increasing adherence to social distancing measures' and it said the following in a section headed 'Persuasion':

- A substantial number of people still do not feel sufficiently personally threatened; it could be that they are reassured by the low death rate in their demographic group, although levels of concern may be rising. Having a good understanding of the risk has been found to be positively associated with adoption of COVID-19 social distancing measures in Hong Kong.

- The perceived level of personal threat needs to be increased among those who are complacent, using hard-hitting evaluation of options for increasing social distancing emotional messaging. To be effective this must also empower people by making clear the actions they can take to reduce the threat.

- Responsibility to others: There seems to be insufficient understanding of, or feelings of responsibility about, people's role in transmitting the infection to others … Messaging about actions need to be framed positively in terms of protecting oneself and the community, and increase confidence that they will be effective.

- Some people will be more persuaded by appeals to play by the rules, some by duty to the community, and some to personal risk.

> All these different approaches are needed. The messaging also needs to take account of the realities of different people's lives. Messaging needs to take account of the different motivational levers and circumstances of different people.

All this could be achieved the SPI-B psychologists said by *using the media to increase the sense of personal threat* which translates as terrify the shit out of the population, including children, so they all do what we want. That's not happened has it? Those excuses for 'journalists' who wouldn't know journalism if it bit them on the arse (the great majority) have played their crucial part in serving this Cult-government Psyop to enslave their own kids and grandkids. How they live with themselves I have no idea. The psychological war has been underpinned by constant government 'Covid' propaganda in almost every television and radio ad break, plus the Internet and print media, which has pounded out the fear with taxpayers footing the bill for their own programming. The result has been people terrified of a 'virus' that doesn't exist or one with a tiny fatality rate even if you believe it does. People walk down the street and around the shops wearing face-nappies damaging their health and psychology while others report those who refuse to be that naïve to the police who turn up in their own face-nappies. I had a cameraman come to my flat and he was so frightened of 'Covid' he came in wearing a mask and refused to shake my hand in case he caught something. He had – naïveitis – and the thought that he worked in the mainstream media was both depressing and made his behaviour perfectly explainable. The fear which has gripped the minds of so many and frozen them into compliance has been carefully cultivated by these psychologists who are really psychopaths. If lives get destroyed and a lot of young people commit suicide it shows our plan is working. SPI-B then turned to compulsion on the public to comply. 'With adequate preparation, rapid change can be achieved', it said. Some countries had introduced mandatory self-isolation on a wide scale without evidence of major public unrest and a large majority of the UK's population appeared to be supportive of more coercive measures with 64 percent of adults saying they would

support putting London under a lockdown (watch the 'polls' which are designed to make people believe that public opinion is in favour or against whatever the subject in hand).

For 'aggressive protective measures' to be effective, the SPI-B paper said, special attention should be devoted to those population groups that are more at risk. Translated from the Orwellian this means making the rest of population feel guilty for not protecting the 'vulnerable' such as old people which the Cult and its agencies were about to kill on an industrial scale with lockdown, lack of treatment and the Gates 'vaccine'. Psychopath psychologists sold their guilt-trip so comprehensively that Los Angeles County Supervisor Hilda Solis reported that children were apologising (from a distance) to their parents and grandparents for bringing 'Covid' into their homes and getting them sick. '… These apologies are just some of the last words that loved ones will ever hear as they die alone,' she said. Gut-wrenchingly Solis then used this childhood tragedy to tell children to stay at home and 'keep your loved ones alive'. Imagine heaping such potentially life-long guilt on a kid when it has absolutely nothing to do with them. These people are deeply disturbed and the psychologists behind this even more so.

Uncivil war – divide and rule

Professional mind-controllers at SPI-B wanted the media to increase a sense of responsibility to others (do as you're told) and promote 'positive messaging' for those actions while in contrast to invoke 'social disapproval' by the unquestioning, obedient, community of anyone with a mind of their own. Again the compliant Goebbels-like media obliged. This is an old, old, trick employed by tyrannies the world over throughout human history. You get the target population to keep the target population in line – *your* line. SPI-B said this could 'play an important role in preventing anti-social behaviour or discouraging failure to enact pro-social behaviour'. For 'anti-social' in the Orwellian parlance of SPI-B see any behaviour that government doesn't approve. SPI-B recommendations said that 'social disapproval' should be accompanied by clear messaging and

promotion of strong collective identity – hence the government and celebrity mantra of 'we're all in this together'. Sure we are. The mind doctors have such contempt for their targets that they think some clueless comedian, actor or singer telling them to do what the government wants will be enough to win them over. We have had UK comedian Lenny Henry, actor Michael Caine and singer Elton John wheeled out to serve the propagandists by urging people to have the DNA-manipulating 'Covid' non-'vaccine'. The role of Henry and fellow black celebrities in seeking to coax a 'vaccine' reluctant black community into doing the government's will was especially stomach-turning. An emotion-manipulating script and carefully edited video featuring these black 'celebs' was such an insult to the intelligence of black people and where's the self-respect of those involved selling their souls to a fascist government agenda? Henry said he heard black people's 'legitimate worries and concerns', but people must 'trust the facts' when they were doing exactly that by not having the 'vaccine'. They had to include the obligatory reference to Black Lives Matter with the line … 'Don't let coronavirus cost even more black lives – because we matter'. My god, it was pathetic. 'I know the vaccine is safe and what it does.' How? 'I'm a comedian and it says so in my script.'

SPI-B said social disapproval needed to be carefully managed to avoid victimisation, scapegoating and misdirected criticism, but they knew that their 'recommendations' would lead to exactly that and the media were specifically used to stir-up the divide-and-conquer hostility. Those who conform like good little baa, baas, are praised while those who have seen through the tidal wave of lies are 'Covidiots'. The awake have been abused by the fast asleep for not conforming to fascism and impositions that the awake know are designed to endanger their health, dehumanise them, and tear asunder the very fabric of human society. We have had the curtain-twitchers and morons reporting neighbours and others to the face-nappied police for breaking 'Covid rules' with fascist police delighting in posting links and phone numbers where this could be done. The Cult cannot impose its will without a compliant police

and military or a compliant population willing to play their part in enslaving themselves and their kids. The words of a pastor in Nazi Germany are so appropriate today:

First they came for the socialists and I did not speak out because I was not a socialist.

Then they came for the trade unionists and I did not speak out because I was not a trade unionist.

Then they came for the Jews and I did not speak out because I was not a Jew.

Then they came for me and there was no one left to speak for me.

Those who don't learn from history are destined to repeat it and so many are.

'Covid' rules: Rewiring the mind

With the background laid out to this gigantic national and global web of psychological manipulation we can put 'Covid' rules into a clear and sinister perspective. Forget the claims about protecting health. 'Covid' rules are about dismantling the human mind, breaking the human spirit, destroying self-respect, and then putting Humpty Dumpty together again as a servile, submissive slave. Social isolation through lockdown and distancing have devastating effects on the human psyche as the psychological psychopaths well know and that's the real reason for them. Humans need contact with each other, discourse, closeness and touch, or they eventually, and literarily, go crazy. Masks, which I will address at some length, fundamentally add to the effects of isolation and the Cult agenda to dehumanise and de-individualise the population. To do this while knowing – in fact *seeking* – this outcome is the very epitome of evil and psychologists involved in this *are* the epitome of evil. They must like all the rest of the Cult demons and their assets stand trial for crimes against humanity on a scale that defies the imagination. Psychopaths in uniform use isolation to break enemy troops and agents and make them subservient and submissive to tell what they know. The technique is rightly considered a form of torture and

torture is most certainly what has been imposed on the human population.

Clinically-insane American psychologist Harry Harlow became famous for his isolation experiments in the 1950s in which he separated baby monkeys from their mothers and imprisoned them for months on end in a metal container or 'pit of despair'. They soon began to show mental distress and depression as any idiot could have predicted. Harlow put other monkeys in steel chambers for three, six or twelve months while denying them any contact with animals or humans. He said that the effects of total social isolation for six months were 'so devastating and debilitating that we had assumed initially that twelve months of isolation would not produce any additional decrement'; but twelve months of isolation 'almost obliterated the animals socially'. This is what the Cult and its psychopaths are doing to you and your children. Even monkeys in partial isolation in which they were not allowed to form relationships with other monkeys became 'aggressive and hostile, not only to others, but also towards their own bodies'. We have seen this in the young as a consequence of lockdown. UK government psychopaths launched a public relations campaign telling people not to hug each other even after they received the 'Covid-19 vaccine' which we were told with more lies would allow a return to 'normal life'. A government source told *The Telegraph*: 'It will be along the lines that it is great that you have been vaccinated, but if you are going to visit your family and hug your grandchildren there is a chance you are going to infect people you love.' The source was apparently speaking from a secure psychiatric facility. Janet Lord, director of Birmingham University's Institute of Inflammation and Ageing, said that parents and grandparents should avoid hugging their children. Well, how can I put it, Ms Lord? Fuck off. Yep, that'll do.

Destroying the kids – where are the parents?

Observe what has happened to people enslaved and isolated by lockdown as suicide and self-harm has soared worldwide,

particularly among the young denied the freedom to associate with their friends. A study of 49,000 people in English-speaking countries concluded that almost half of young adults are at clinical risk of mental health disorders. A national survey in America of 1,000 currently enrolled high school and college students found that 5 percent reported attempting suicide during the pandemic. Data from the US CDC's National Syndromic Surveillance Program from January 1st to October 17th, 2020, revealed a *31 percent* increase in mental health issues among adolescents aged 12 to 17 compared with 2019. The CDC reported that America in general suffered the biggest drop in life expectancy since World War Two as it fell by a year in the first half of 2020 as a result of 'deaths of despair' – overdoses and suicides. Deaths of despair have leapt by more than 20 percent during lockdown and include the highest number of fatal overdoses ever recorded in a single year – 81,000. Internet addiction is another consequence of being isolated at home which lowers interest in physical activities as kids fall into inertia and what's the point? Children and young people are losing hope and giving up on life, sometimes literally. A 14-year-old boy killed himself in Maryland because he had 'given up' when his school district didn't reopen; an 11-year-old boy shot himself during a zoom class; a teenager in Maine succumbed to the isolation of the 'pandemic' when he ended his life after experiencing a disrupted senior year at school. Children as young as nine have taken their life and all these stories can be repeated around the world. Careers are being destroyed before they start and that includes those in sport in which promising youngsters have not been able to take part. The plan of the psycho-psychologists is working all right. Researchers at Cambridge University found that lockdowns cause significant harm to children's mental health. Their study was published in the *Archives of Disease in Childhood*, and followed 168 children aged between 7 and 11. The researchers concluded:

> During the UK lockdown, children's depression symptoms have increased substantially, relative to before lockdown. The scale of this effect has direct relevance for the continuation of different elements of lockdown policy, such as complete or partial school closures …

… Specifically, we observed a statistically significant increase in ratings of depression, with a medium-to-large effect size. Our findings emphasise the need to incorporate the potential impact of lockdown on child mental health in planning the ongoing response to the global pandemic and the recovery from it.

Not a chance when the Cult's psycho-psychologists were getting exactly what they wanted. The UK's Royal College of Paediatrics and Child Health has urged parents to look for signs of eating disorders in children and young people after a three to four fold increase. Specialists say the 'pandemic' is a major reason behind the rise. You don't say. The College said isolation from friends during school closures, exam cancellations, loss of extra-curricular activities like sport, and an increased use of social media were all contributory factors along with fears about the virus (psycho-psychologists again), family finances, and students being forced to quarantine. Doctors said young people were becoming severely ill by the time they were seen with 'Covid' regulations reducing face-to-face consultations. Nor is it only the young that have been devastated by the psychopaths. Like all bullies and cowards the Cult is targeting the young, elderly, weak and infirm. A typical story was told by a British lady called Lynn Parker who was not allowed to visit her husband in 2020 for the last ten and half months of his life 'when he needed me most' between March 20th and when he died on December 19th. This vacates the criminal and enters the territory of evil. The emotional impact on the immune system alone is immense as are the number of people of all ages worldwide who have died as a result of Cult-demanded, Gates-demanded, lockdowns.

Isolation is torture

The experience of imposing solitary confinement on millions of prisoners around the world has shown how a large percentage become 'actively psychotic and/or acutely suicidal'. Social isolation has been found to trigger 'a specific psychiatric syndrome, characterized by hallucinations; panic attacks; overt paranoia; diminished impulse control; hypersensitivity to external stimuli; and difficulties with thinking, concentration and memory'. Juan Mendez,

a United Nations rapporteur (investigator), said that isolation is a form of torture. Research has shown that even after isolation prisoners find it far more difficult to make social connections and I remember chatting to a shop assistant after one lockdown who told me that when her young son met another child again he had no idea how to act or what to do. Hannah Flanagan, Director of Emergency Services at Journey Mental Health Center in Dane County, Wisconsin, said: 'The specificity about Covid social distancing and isolation that we've come across as contributing factors to the suicides are really new to us this year.' But they are not new to those that devised them. They are getting the effect they want as the population is psychologically dismantled to be rebuilt in a totally different way. Children and the young are particularly targeted. They will be the adults when the full-on fascist AI-controlled technocracy is planned to be imposed and they are being prepared to meekly submit. At the same time older people who still have a memory of what life was like before – and how fascist the new normal really is – are being deleted. You are going to see efforts to turn the young against the old to support this geriatric genocide. Hannah Flanagan said the big increase in suicide in her county proved that social isolation is not only harmful, but deadly. Studies have shown that isolation from others is one of the main risk factors in suicide and even more so with women. Warnings that lockdown could create a 'perfect storm' for suicide were ignored. After all this was one of the *reasons* for lockdown. Suicide, however, is only the most extreme of isolation consequences. There are many others. Dr Dhruv Khullar, assistant professor of healthcare policy at Weill Cornell Medical College, said in a *New York Times* article in 2016 long before the fake 'pandemic':

> A wave of new research suggests social separation is bad for us. Individuals with less social connection have disrupted sleep patterns, altered immune systems, more inflammation and higher levels of stress hormones. One recent study found that isolation increases the risk of heart disease by 29 percent and stroke by 32 percent. Another analysis that pooled data from 70 studies and 3.4 million people found that socially isolated individuals had a 30 percent higher risk of dying in the next seven years, and that this effect was largest in middle age.

Loneliness can accelerate cognitive decline in older adults, and isolated individuals are twice as likely to die prematurely as those with more robust social interactions. These effects start early: Socially isolated children have significantly poorer health 20 years later, even after controlling for other factors. All told, loneliness is as important a risk factor for early death as obesity and smoking.

There you have proof from that one article alone four years before 2020 that those who have enforced lockdown, social distancing and isolation knew what the effect would be and that is even more so with professional psychologists that have been driving the policy across the globe. We can go back even further to the years 2000 and 2003 and the start of a major study on the effects of isolation on health by Dr Janine Gronewold and Professor Dirk M. Hermann at the University Hospital in Essen, Germany, who analysed data on 4,316 people with an average age of 59 who were recruited for the long-term research project. They found that socially isolated people are more than 40 percent more likely to have a heart attack, stroke, or other major cardiovascular event and nearly 50 percent more likely to die from any cause. Given the financial Armageddon unleashed by lockdown we should note that the study found a relationship between increased cardiovascular risk and lack of financial support. After excluding other factors social isolation was still connected to a 44 percent increased risk of cardiovascular problems and a 47 percent increased risk of death by any cause. Lack of financial support was associated with a 30 percent increase in the risk of cardiovascular health events. Dr Gronewold said it had been known for some time that feeling lonely or lacking contact with close friends and family can have an impact on physical health and the study had shown that having strong social relationships is of high importance for heart health. Gronewold said they didn't understand yet why people who are socially isolated have such poor health outcomes, but this was obviously a worrying finding, particularly during these times of prolonged social distancing. Well, it can be explained on many levels. You only have to identify the point in the body where people feel loneliness and missing people they are parted from – it's in the centre of the chest where they feel the ache of loneliness and the ache of missing people. 'My heart aches for

you' … 'My heart aches for some company.' I will explain this more in the chapter Escaping Wetiko, but when you realise that the body is the mind – they are expressions of each other – the reason why state of the mind dictates state of the body becomes clear.

American psychologist Ranjit Powar was highlighting the effects of lockdown isolation as early as April, 2020. She said humans have evolved to be social creatures and are wired to live in interactive groups. Being isolated from family, friends and colleagues could be unbalancing and traumatic for most people and could result in short or even long-term psychological and physical health problems. An increase in levels of anxiety, aggression, depression, forgetfulness and hallucinations were possible psychological effects of isolation. 'Mental conditions may be precipitated for those with underlying pre-existing susceptibilities and show up in many others without any pre-condition.' Powar said personal relationships helped us cope with stress and if we lost this outlet for letting off steam the result can be a big emotional void which, for an average person, was difficult to deal with. 'Just a few days of isolation can cause increased levels of anxiety and depression' – so what the hell has been the effect on the global population of *18 months* of this at the time of writing? Powar said: 'Add to it the looming threat of a dreadful disease being repeatedly hammered in through the media and you have a recipe for many shades of mental and physical distress.' For those with a house and a garden it is easy to forget that billions have had to endure lockdown isolation in tiny overcrowded flats and apartments with nowhere to go outside. The psychological and physical consequences of this are unimaginable and with lunatic and abusive partners and parents the consequences have led to tremendous increases in domestic and child abuse and alcoholism as people seek to shut out the horror. Ranjit Powar said:

Staying in a confined space with family is not all a rosy picture for everyone. It can be extremely oppressive and claustrophobic for large low-income families huddled together in small single-room houses. Children here are not lucky enough to have many board/electronic games or books to keep them occupied.

Add to it the deep insecurity of running out of funds for food and basic necessities. On the other hand, there are people with dysfunctional family dynamics, such as domineering, abusive or alcoholic partners, siblings or parents which makes staying home a period of trial. Incidence of suicide and physical abuse against women has shown a worldwide increase. Heightened anxiety and depression also affect a person's immune system, making them more susceptible to illness.

To think that Powar's article was published on April 11th, 2020.

Six-feet fantasy

Social (unsocial) distancing demanded that people stay six feet or two metres apart. UK government advisor Robert Dingwall from the New and Emerging Respiratory Virus Threats Advisory Group said in a radio interview that the two-metre rule was 'conjured up out of nowhere' and was not based on science. No, it was not based on *medical* science, but it didn't come out of nowhere. The distance related to *psychological* science. Six feet/two metres was adopted in many countries and we were told by people like the criminal Anthony Fauci and his ilk that it was founded on science. Many schools could not reopen because they did not have the space for six-feet distancing. Then in March, 2021, after a year of six-feet 'science', a study published in the *Journal of Infectious Diseases* involving more than 500,000 students and almost 100,000 staff over 16 weeks revealed no significant difference in 'Covid' cases between six feet and three feet and Fauci changed his tune. Now three feet was okay. There is no difference between six feet and three *inches* when there is no 'virus' and they got away with six feet for psychological reasons for as long as they could. I hear journalists and others talk about 'unintended consequences' of lockdown. They are not *unintended* at all; they have been coldly-calculated for a specific outcome of human control and that's why super-psychopaths like Gates have called for them so vehemently. Super-psychopath psychologists have demanded them and psychopathic or clueless, spineless, politicians have gone along with them by 'following the science'. But it's not science at all. 'Science' is not what is; it's only what people can be manipulated to believe it is. The whole 'Covid' catastrophe is

founded on mind control. Three word or three statement mantras issued by the UK government are a well-known mind control technique and so we've had 'Stay home/protect the NHS/save lives', 'Stay alert/control the virus/save lives' and 'hands/face/space'. One of the most vocal proponents of extreme 'Covid' rules in the UK has been Professor Susan Michie, a member of the British Communist Party, who is not a medical professional. Michie is the director of the Centre for Behaviour Change at University College London. She is a *behavioural psychologist* and another filthy rich 'Marxist' who praised China's draconian lockdown. She was known by fellow students at Oxford University as 'Stalin's nanny' for her extreme Marxism. Michie is an influential member of the UK government's Scientific Advisory Group for Emergencies (SAGE) and behavioural manipulation groups which have dominated 'Covid' policy. She is a consultant adviser to the World Health Organization on 'Covid-19' and behaviour. Why the hell are lockdowns anything to do with her when they are claimed to be about health? Why does a behavioural psychologist from a group charged with changing the behaviour of the public want lockdown, human isolation and mandatory masks? Does that question really need an answer? Michie *absolutely* has to explain herself before a Nuremberg court when humanity takes back its world again and even more so when you see the consequences of masks that she demands are compulsory. This is a Michie classic:

> The benefits of getting primary school children to wear masks is that regardless of what little degree of transmission is occurring in those age groups it could help normalise the practice. Young children wearing masks may be more likely to get their families to accept masks.

Those words alone should carry a prison sentence when you ponder on the callous disregard for children involved and what a statement it makes about the mind and motivations of Susan Michie. What a lovely lady and what she said there encapsulates the mentality of the psychopaths behind the 'Covid' horror. Let us compare what Michie said with a countrywide study in Germany published at researchsquare.com involving 25,000 school children and 17,854 health complaints submitted by parents. Researchers

found that masks are harming children physically, psychologically, and behaviourally with 24 health issues associated with mask wearing. They include: shortness of breath (29.7%); dizziness (26.4%); increased headaches (53%); difficulty concentrating (50%); drowsiness or fatigue (37%); and malaise (42%). Nearly a third of children experienced more sleep issues than before and a quarter developed new fears. Researchers found health issues and other impairments in 68 percent of masked children covering their faces for an average of 4.5 hours a day. Hundreds of those taking part experienced accelerated respiration, tightness in the chest, weakness, and short-term impairment of consciousness. A reminder of what Michie said again:

The benefits of getting primary school children to wear masks is that regardless of what little degree of transmission is occurring in those age groups it could help normalise the practice. Young children wearing masks may be more likely to get their families to accept masks.

Psychopaths in government and psychology now have children and young people – plus all the adults – wearing masks for hours on end while clueless teachers impose the will of the psychopaths on the young they should be protecting. What the hell are parents doing?

Cult lab rats

We have some schools already imposing on students microchipped buzzers that activate when they get 'too close' to their pals in the way they do with lab rats. How apt. To the Cult and its brain-dead servants our children *are* lab rats being conditioned to be unquestioning, dehumanised slaves for the rest of their lives. Children and young people are being weaned and frightened away from the most natural human instincts including closeness and touch. I have tracked in the books over the years how schools were banning pupils from greeting each other with a hug and the whole Cult-induced Me Too movement has terrified men and boys from a relaxed and natural interaction with female friends and work colleagues to the point where many men try never to be in a room

alone with a woman that's not their partner. Airhead celebrities have as always played their virtue-signalling part in making this happen with their gross exaggeration. For every monster like Harvey Weinstein there are at least tens of thousands of men that don't treat women like that; but everyone must be branded the same and policy changed for them as well as the monster. I am going to be using the word 'dehumanise' many times in this chapter because that is what the Cult is seeking to do and it goes very deep as we shall see. Don't let them kid you that social distancing is planned to end one day. That's not the idea. We are seeing more governments and companies funding and producing wearable gadgets to keep people apart and they would not be doing that if this was meant to be short-term. A tech start-up company backed by GCHQ, the British Intelligence and military surveillance headquarters, has created a social distancing wrist sensor that alerts people when they get too close to others. The CIA has also supported tech companies developing similar devices. The wearable sensor was developed by Tended, one of a number of start-up companies supported by GCHQ (see the CIA and DARPA). The device can be worn on the wrist or as a tag on the waistband and will vibrate whenever someone wearing the device breaches social distancing and gets anywhere near natural human contact. The company had a lucky break in that it was developing a distancing sensor when the 'Covid' hoax arrived which immediately provided a potentially enormous market. How fortunate. The government in big-time Cult-controlled Ontario in Canada is investing $2.5 million in wearable contact tracing technology that 'will alert users if they may have been exposed to the Covid-19 in the workplace and will beep or vibrate if they are within six feet of another person'. Facedrive Inc., the technology company behind this, was founded in 2016 with funding from the Ontario Together Fund and obviously they, too, had a prophet on the board of directors. The human surveillance and control technology is called TraceSCAN and would be worn by the human cyborgs in places such as airports, workplaces, construction sites, care homes and … *schools*.

I emphasise schools with children and young people the prime targets. You know what is planned for society as a whole if you keep your eyes on the schools. They have always been places where the state program the next generation of slaves to be its compliant worker-ants – or Woker-ants these days; but in the mist of the 'Covid' madness they have been transformed into mind laboratories on a scale never seen before. Teachers and head teachers are just as programmed as the kids – often more so. Children are kept apart from human interaction by walk lanes, classroom distancing, staggered meal times, masks, and the rolling-out of buzzer systems. Schools are now physically laid out as a laboratory maze for lab-rats. Lunatics at a school in Anchorage, Alaska, who should be prosecuted for child abuse, took away desks and forced children to kneel (know your place) on a mat for five hours a day while wearing a mask and using their chairs as a desk. How this was supposed to impact on a 'virus' only these clinically insane people can tell you and even then it would be clap-trap. The school banned recess (interaction), art classes (creativity), and physical exercise (getting body and mind moving out of inertia). Everyone behind this outrage should be in jail or better still a mental institution. The behavioural manipulators are all for this dystopian approach to schools. Professor Susan Michie, the mind-doctor and British Communist Party member, said it was wrong to say that schools were safe. They had to be made so by 'distancing', masks and ventilation (sitting all day in the cold). I must ask this lady round for dinner on a night I know I am going to be out and not back for weeks. She probably wouldn't be able to make it, anyway, with all the visits to her own psychologist she must have block-booked.

Masking identity

I know how shocking it must be for you that a behaviour manipulator like Michie wants everyone to wear masks which have long been a feature of mind-control programs like the infamous MKUltra in the United States, but, there we are. We live and learn. I spent many years from 1996 to right across the millennium

researching mind control in detail on both sides of the Atlantic and elsewhere. I met a large number of mind-control survivors and many had been held captive in body and mind by MKUltra. MK stands for mind-control, but employs the German spelling in deference to the Nazis spirited out of Germany at the end of World War Two by Operation Paperclip in which the US authorities, with help from the Vatican, transported Nazi mind-controllers and engineers to America to continue their work. Many of them were behind the creation of NASA and they included Nazi scientist and SS officer Wernher von Braun who swapped designing V-2 rockets to bombard London with designing the Saturn V rockets that powered the NASA moon programme's Apollo craft. I think I may have mentioned that the Cult has no borders. Among Paperclip escapees was Josef Mengele, the Angel of Death in the Nazi concentration camps where he conducted mind and genetic experiments on children often using twins to provide a control twin to measure the impact of his 'work' on the other. If you want to observe the Cult mentality in all its extremes of evil then look into the life of Mengele. I have met many people who suffered mercilessly under Mengele in the United States where he operated under the name Dr Greene and became a stalwart of MKUltra programming and torture. Among his locations was the underground facility in the Mojave Desert in California called the China Lake Naval Weapons Station which is almost entirely below the surface. My books *The Biggest Secret*, *Children of the Matrix* and *The Perception Deception* have the detailed background to MKUltra.

The best-known MKUltra survivor is American Cathy O'Brien. I first met her and her late partner Mark Phillips at a conference in Colorado in 1996. Mark helped her escape and deprogram from decades of captivity in an offshoot of MKUltra known as Project Monarch in which 'sex slaves' were provided for the rich and famous including Father George Bush, Dick Cheney and the Clintons. Read Cathy and Mark's book *Trance-Formation of America* and if you are new to this you will be shocked to the core. I read it in 1996 shortly before, with the usual synchronicity of my life, I found

myself given a book table at the conference right next to hers. MKUltra never ended despite being very publicly exposed (only a small part of it) in the 1970s and continues in other guises. I am still in touch with Cathy. She contacted me during 2020 after masks became compulsory in many countries to tell me how they were used as part of MKUltra programming. I had been observing 'Covid regulations' and the relationship between authority and public for months. I saw techniques that I knew were employed on individuals in MKUltra being used on the global population. I had read many books and manuals on mind control including one called *Silent Weapons for Quiet Wars* which came to light in the 1980s and was a guide on how to perceptually program on a mass scale. 'Silent Weapons' refers to mind-control. I remembered a line from the manual as governments, medical authorities and law enforcement agencies have so obviously talked to – or rather at – the adult population since the 'Covid' hoax began as if they are children. The document said:

> If a person is spoken to by a T.V. advertiser as if he were a twelve-year-old, then, due to suggestibility, he will, with a certain probability, respond or react to that suggestion with the uncritical response of a twelve-year-old and will reach in to his economic reservoir and deliver its energy to buy that product on impulse when he passes it in the store.

That's why authority has spoken to adults like children since all this began.

Why did Michael Jackson wear masks?

Every aspect of the 'Covid' narrative has mind-control as its central theme. Cathy O'Brien wrote an article for davidicke.com about the connection between masks and mind control. Her daughter Kelly who I first met in the 1990s was born while Cathy was still held captive in MKUltra. Kelly was forced to wear a mask as part of her programming from the age of *two* to dehumanise her, target her sense of individuality and reduce the amount of oxygen her brain and body received. *Bingo*. This is the real reason for compulsory

masks, why they have been enforced en masse, and why they seek to increase the number they demand you wear. First one, then two, with one disgraceful alleged 'doctor' recommending four which is nothing less than a death sentence. Where and how often they must be worn is being expanded for the purpose of mass mind control and damaging respiratory health which they can call 'Covid-19'. Canada's government headed by the man-child Justin Trudeau, says it's fine for children of two and older to wear masks. An insane 'study' in Italy involving just 47 children concluded there was no problem for babies as young as *four months* wearing them. Even after people were 'vaccinated' they were still told to wear masks by the criminal that is Anthony Fauci. Cathy wrote that mandating masks is allowing the authorities literally to control the air we breathe which is what was done in MKUltra. You might recall how the singer Michael Jackson wore masks and there is a reason for that. He was subjected to MKUltra mind control through Project Monarch and his psyche was scrambled by these simpletons. Cathy wrote:

In MKUltra Project Monarch mind control, Michael Jackson had to wear a mask to silence his voice so he could not reach out for help. Remember how he developed that whisper voice when he wasn't singing? Masks control the mind from the outside in, like the redefining of words is doing. By controlling what we can and cannot say for fear of being labeled racist or beaten, for example, it ultimately controls thought that drives our words and ultimately actions (or lack thereof).

Likewise, a mask muffles our speech so that we are not heard, which controls voice … words … mind. This is Mind Control. Masks are an obvious mind control device, and I am disturbed so many people are complying on a global scale. Masks depersonalize while making a person feel as though they have no voice. It is a barrier to others. People who would never choose to comply but are forced to wear a mask in order to keep their job, and ultimately their family fed, are compromised. They often feel shame and are subdued. People have stopped talking with each other while media controls the narrative.

The 'no voice' theme has often become literal with train passengers told not to speak to each other in case they pass on the 'virus', singing banned for the same reason and bonkers California officials telling people riding roller coasters that they cannot shout and scream. Cathy said she heard every day from healed MKUltra survivors who cannot wear a mask without flashing back on ways

their breathing was controlled – 'from ball gags and penises to water boarding'. She said that through the years when she saw images of people in China wearing masks 'due to pollution' that it was really to control their oxygen levels. 'I knew it was as much of a population control mechanism of depersonalisation as are burkas', she said. Masks are another Chinese communist/fascist method of control that has been swept across the West as the West becomes China at lightning speed since we entered 2020.

Mask-19

There are other reasons for mandatory masks and these include destroying respiratory health to call it 'Covid-19' and stunting brain development of children and the young. Dr Margarite Griesz-Brisson MD, PhD, is a Consultant Neurologist and Neurophysiologist and the Founder and Medical Director of the London Neurology and Pain Clinic. Her CV goes down the street and round the corner. She is clearly someone who cares about people and won't parrot the propaganda. Griesz-Brisson has a PhD in pharmacology, with special interest in neurotoxicology, environmental medicine, neuroregeneration and neuroplasticity (the way the brain can change in the light of information received). She went public in October, 2020, with a passionate warning about the effects of mask-wearing laws:

> The reinhalation of our exhaled air will without a doubt create oxygen deficiency and a flooding of carbon dioxide. We know that the human brain is very sensitive to oxygen deprivation. There are nerve cells for example in the hippocampus that can't be longer than 3 minutes without oxygen – they cannot survive. The acute warning symptoms are headaches, drowsiness, dizziness, issues in concentration, slowing down of reaction time – reactions of the cognitive system.

Oh, I know, let's tell bus, truck and taxi drivers to wear them and people working machinery. How about pilots, doctors and police? Griesz-Brisson makes the important point that while the symptoms she mentions may fade as the body readjusts this does not alter the fact that people continue to operate in oxygen deficit with long list of

potential consequences. She said it was well known that neurodegenerative diseases take years or decades to develop. 'If today you forget your phone number, the breakdown in your brain would have already started 20 or 30 years ago.' She said degenerative processes in your brain are getting amplified as your oxygen deprivation continues through wearing a mask. Nerve cells in the brain are unable to divide themselves normally in these circumstances and lost nerve cells will no longer be regenerated. 'What is gone is gone.' Now consider that people like shop workers and *schoolchildren* are wearing masks for hours every day. What in the name of sanity is going to be happening to them? 'I do not wear a mask, I need my brain to think', Griesz-Brisson said, 'I want to have a clear head when I deal with my patients and not be in a carbon dioxide-induced anaesthesia'. If you are told to wear a mask anywhere ask the organisation, police, store, whatever, for their risk assessment on the dangers and negative effects on mind and body of enforcing mask-wearing. They won't have one because it has never been done not even by government. All of them must be subject to class-action lawsuits as the consequences come to light. They don't do mask risk assessments for an obvious reason. They know what the conclusions would be and independent scientific studies that *have* been done tell a horror story of consequences.

'Masks are criminal'

Dr Griesz-Brisson said that for children and adolescents, masks are an absolute no-no. They had an extremely active and adaptive immune system and their brain was incredibly active with so much to learn. 'The child's brain, or the youth's brain, is thirsting for oxygen.' The more metabolically active an organ was, the more oxygen it required; and in children and adolescents every organ was metabolically active. Griesz-Brisson said that to deprive a child's or adolescent's brain of oxygen, or to restrict it in any way, was not only dangerous to their health, it was absolutely criminal. 'Oxygen deficiency inhibits the development of the brain, and the damage that has taken place as a result CANNOT be reversed.' Mind

manipulators of MKUltra put masks on two-year-olds they wanted to neurologically rewire and you can see why. Griesz-Brisson said a child needs the brain to learn and the brain needs oxygen to function. 'We don't need a clinical study for that. This is simple, indisputable physiology.' Consciously and purposely induced oxygen deficiency was an absolutely deliberate health hazard, and an absolute medical contraindication which means that 'this drug, this therapy, this method or measure should not be used, and is not allowed to be used'. To coerce an entire population to use an absolute medical contraindication by force, she said, there had to be definite and serious reasons and the reasons must be presented to competent interdisciplinary and independent bodies to be verified and authorised. She had this warning of the consequences that were coming if mask wearing continued:

When, in ten years, dementia is going to increase exponentially, and the younger generations couldn't reach their god-given potential, it won't help to say 'we didn't need the masks'. I know how damaging oxygen deprivation is for the brain, cardiologists know how damaging it is for the heart, pulmonologists know how damaging it is for the lungs. Oxygen deprivation damages every single organ. Where are our health departments, our health insurance, our medical associations? It would have been their duty to be vehemently against the lockdown and to stop it and stop it from the very beginning.

Why do the medical boards issue punishments to doctors who give people exemptions? Does the person or the doctor seriously have to prove that oxygen deprivation harms people? What kind of medicine are our doctors and medical associations representing? Who is responsible for this crime? The ones who want to enforce it? The ones who let it happen and play along, or the ones who don't prevent it?

All of the organisations and people she mentions there either answer directly to the Cult or do whatever hierarchical levels above them tell them to do. The outcome of both is the same. 'It's not about masks, it's not about viruses, it's certainly not about your health', Griesz-Brisson said. 'It is about much, much more. I am not participating. I am not afraid.' They were taking our air to breathe and there was no unfounded medical exemption from face masks. Oxygen deprivation was dangerous for every single brain. It had to be the free decision of every human being whether they want to

wear a mask that was absolutely ineffective to protect themselves from a virus. She ended by rightly identifying where the responsibility lies for all this:

> The imperative of the hour is personal responsibility. We are responsible for what we think, not the media. We are responsible for what we do, not our superiors. We are responsible for our health, not the World Health Organization. And we are responsible for what happens in our country, not the government.

Halle-bloody-lujah.

But surgeons wear masks, right?

Independent studies of mask-wearing have produced a long list of reports detailing mental, emotional and physical dangers. What a definition of insanity to see police officers imposing mask-wearing on the public which will cumulatively damage their health while the police themselves wear masks that will cumulatively damage *their* health. It's utter madness and both public and police do this because 'the government says so' – yes a government of brain-donor idiots like UK Health Secretary Matt Hancock reading the 'follow the science' scripts of psychopathic, lunatic psychologists. The response you get from Stockholm syndrome sufferers defending the very authorities that are destroying them and their families is that 'surgeons wear masks'. This is considered the game, set and match that they must work and don't cause oxygen deficit. Well, actually, scientific studies have shown that they *do* and oxygen levels are monitored in operating theatres to compensate. Surgeons wear masks to stop spittle and such like dropping into open wounds – not to stop 'viral particles' which are so miniscule they can only be seen through an electron microscope. Holes in the masks are significantly bigger than 'viral particles' and if you sneeze or cough they will breach the mask. I watched an incredibly disingenuous 'experiment' that claimed to prove that masks work in catching 'virus' material from the mouth and nose. They did this with a slow motion camera and the mask did block big stuff which stayed inside the mask and

against the face to be breathed in or cause infections on the face as we have seen with many children. 'Viral particles', however, would never have been picked up by the camera as they came through the mask when they are far too small to be seen. The 'experiment' was therefore disingenuous *and* useless.

Studies have concluded that wearing masks in operating theatres (and thus elsewhere) make no difference to preventing infection while the opposite is true with toxic shite building up in the mask and this had led to an explosion in tooth decay and gum disease dubbed by dentists 'mask mouth'. You might have seen the Internet video of a furious American doctor urging people to take off their masks after a four-year-old patient had been rushed to hospital the night before and nearly died with a lung infection that doctors sourced to mask wearing. A study in the journal *Cancer Discovery* found that inhalation of harmful microbes can contribute to advanced stage lung cancer in adults and long-term use of masks can help breed dangerous pathogens. Microbiologists have said frequent mask wearing creates a moist environment in which microbes can grow and proliferate before entering the lungs. The Canadian Agency for Drugs and Technologies in Health, or CADTH, a Canadian national organisation that provides research and analysis to healthcare decision-makers, said this as long ago as 2013 in a report entitled 'Use of Surgical Masks in the Operating Room: A Review of the Clinical Effectiveness and Guidelines'. It said:

- No evidence was found to support the use of surgical face masks to reduce the frequency of surgical site infections
- No evidence was found on the effectiveness of wearing surgical face masks to protect staff from infectious material in the operating room.
- Guidelines recommend the use of surgical face masks by staff in the operating room to protect both operating room staff and patients (despite the lack of evidence).

We were told that the world could go back to 'normal' with the arrival of the 'vaccines'. When they came, fraudulent as they are, the story changed as I knew that it would. We are in the midst of transforming 'normal', not going back to it. Mary Ramsay, head of immunisation at Public Health England, echoed the words of US criminal Anthony Fauci who said masks and other regulations must stay no matter if people are vaccinated. The Fauci idiot continued to wear two masks – different colours so both could be clearly seen – after he *claimed* to have been vaccinated. Senator Rand Paul told Fauci in one exchange that his double-masks were 'theatre' and he was right. It's all theatre. Mary Ramsay back-tracked on the vaccine-return-to-normal theme when she said the public may need to wear masks and social-distance for years despite the jabs. 'People have got used to those lower-level restrictions now, and [they] can live with them', she said telling us what the idea has been all along. 'The vaccine does not give you a pass, even if you have had it, you must continue to follow all the guidelines' said a Public Health England statement which reneged on what we had been told before and made having the 'vaccine' irrelevant to 'normality' even by the official story. Spain's fascist government trumped everyone by passing a law mandating the wearing of masks on the beach and even when swimming in the sea. The move would have devastated what's left of the Spanish tourist industry, posed potential breathing dangers to swimmers and had Northern European sunbathers walking around with their forehead brown and the rest of their face white as a sheet. The ruling was so crazy that it had to be retracted after pressure from public and tourist industry, but it confirmed where the Cult wants to go with masks and how clinically insane authority has become. The determination to make masks permanent and hide the serious dangers to body and mind can be seen in the censorship of scientist Professor Denis Rancourt by Bill Gates-funded academic publishing website ResearchGate over his papers exposing the dangers and uselessness of masks. Rancourt said:

ResearchGate today has permanently locked my account, which I have had since 2015. Their reasons graphically show the nature of their attack against democracy, and their corruption of

science … By their obscene non-logic, a scientific review of science articles reporting on harms caused by face masks has a 'potential to cause harm'. No criticism of the psychological device (face masks) is tolerated, if the said criticism shows potential to influence public policy.

This is what happens in a fascist world.

Where are the 'greens' (again)?

Other dangers of wearing masks especially regularly relate to the inhalation of minute plastic fibres into the lungs and the deluge of discarded masks in the environment and oceans. Estimates predicted that more than 1.5 billion disposable masks will end up in the world's oceans every year polluting the water with tons of plastic and endangering marine wildlife. Studies project that humans are using 129 billion face masks each month worldwide – about three million a minute. Most are disposable and made from plastic, non-biodegradable microfibers that break down into smaller plastic particles that become widespread in ecosystems. They are littering cities, clogging sewage channels and turning up in bodies of water. I have written in other books about the immense amounts of microplastics from endless sources now being absorbed into the body. Rolf Halden, director of the Arizona State University (ASU) Biodesign Center for Environmental Health Engineering, was the senior researcher in a 2020 study that analysed 47 human tissue samples and found microplastics in all of them. 'We have detected these chemicals of plastics in every single organ that we have investigated', he said. I wrote in *The Answer* about the world being deluged with microplastics. A study by the Worldwide Fund for Nature (WWF) found that people are consuming on average every week some 2,000 tiny pieces of plastic mostly through water and also through marine life and the air. Every year humans are ingesting enough microplastics to fill a heaped dinner plate and in a life-time of 79 years it is enough to fill two large waste bins. Marco Lambertini, WWF International director general said: 'Not only are plastics polluting our oceans and waterways and killing marine life – it's in all of us and we can't escape consuming plastics,' American

geologists found tiny plastic fibres, beads and shards in rainwater samples collected from the remote slopes of the Rocky Mountain National Park near Denver, Colorado. Their report was headed: 'It is raining plastic.' Rachel Adams, senior lecturer in Biomedical Science at Cardiff Metropolitan University, said that among health consequences are internal inflammation and immune responses to a 'foreign body'. She further pointed out that microplastics become carriers of toxins including mercury, pesticides and dioxins (a known cause of cancer and reproductive and developmental problems). These toxins accumulate in the fatty tissues once they enter the body through microplastics. Now this is being compounded massively by people putting plastic on their face and throwing it away.

Workers exposed to polypropylene plastic fibres known as 'flock' have developed 'flock worker's lung' from inhaling small pieces of the flock fibres which can damage lung tissue, reduce breathing capacity and exacerbate other respiratory problems. *Now* … commonly used surgical masks have three layers of melt-blown textiles made of … polypropylene. We have billions of people putting these microplastics against their mouth, nose and face for hours at a time day after day in the form of masks. How does anyone think that will work out? I mean – what could possibly go wrong? We posted a number of scientific studies on this at davidicke.com, but when I went back to them as I was writing this book the links to the science research website where they were hosted were dead. Anything that challenges the official narrative in any way is either censored or vilified. The official narrative is so unsupportable by the evidence that only deleting the truth can protect it. A study by Chinese scientists still survived – with the usual twist which it why it was still active, I guess. Yes, they found that virtually all the masks they tested increased the daily intake of microplastic fibres, but people should still wear them because the danger from the 'virus' was worse said the crazy 'team' from the Institute of Hydrobiology in Wuhan. Scientists first discovered microplastics in lung tissue of some patients who died of lung cancer

in the 1990s. Subsequent studies have confirmed the potential health damage with the plastic degrading slowly and remaining in the lungs to accumulate in volume. Wuhan researchers used a machine simulating human breathing to establish that masks shed up to nearly 4,000 microplastic fibres in a month with reused masks producing more. Scientists said some masks are laced with toxic chemicals and a variety of compounds seriously restricted for both health and environmental reasons. They include cobalt (used in blue dye) and formaldehyde known to cause watery eyes, burning sensations in the eyes, nose, and throat, plus coughing, wheezing and nausea. No – that must be 'Covid-19'.

Mask 'worms'

There is another and potentially even more sinister content of masks. Mostly new masks of different makes filmed under a microscope around the world have been found to contain strange black fibres or 'worms' that appear to move or 'crawl' by themselves and react to heat and water. The nearest I have seen to them are the self-replicating fibres that are pulled out through the skin of those suffering from Morgellons disease which has been connected to the phenomena of 'chemtrails' which I will bring into the story later on. Morgellons fibres continue to grow outside the body and have a form of artificial intelligence. Black 'worm' fibres in masks have that kind of feel to them and there is a nanotechnology technique called 'worm micelles' which carry and release drugs or anything else you want to deliver to the body. For sure the suppression of humanity by mind altering drugs is the Cult agenda big time and the more excuses they can find to gain access to the body the more opportunities there are to make that happen whether through 'vaccines' or masks pushed against the mouth and nose for hours on end.

So let us summarise the pros and cons of masks:

Against masks: Breathing in your own carbon dioxide; depriving the body and brain of sufficient oxygen; build-up of toxins in the mask that can be breathed into the lungs and cause rashes on the face and 'mask-mouth'; breathing microplastic fibres and toxic chemicals into the lungs; dehumanisation and deleting individualisation by literally making people faceless; destroying human emotional interaction through facial expression and deleting parental connection with their babies which look for guidance to their facial expression.

For masks: They don't protect you from a 'virus' that doesn't exist and even if it did 'viral' particles are so minute they are smaller than the holes in the mask.

Governments, police, supermarkets, businesses, transport companies, and all the rest who seek to impose masks have done no risk assessment on their consequences for health and psychology and are now open to group lawsuits when the impact becomes clear with a cumulative epidemic of respiratory and other disease. Authorities will try to exploit these effects and hide the real cause by dubbing them 'Covid-19'. Can you imagine setting out to force the population to wear health-destroying masks without doing any assessment of the risks? It is criminal and it is evil, but then how many people targeted in this way, who see their children told to wear them all day at school, have asked for a risk assessment? Billions can't be imposed upon by the few unless the billions allow it. Oh, yes, with just a tinge of irony, 85 percent of all masks made worldwide come from *China*.

Wash your hands in toxic shite

'Covid' rules include the use of toxic sanitisers and again the health consequences of constantly applying toxins to be absorbed through the skin is obvious to any level of Renegade Mind. America's Food and Drug Administration (FDA) said that sanitisers are drugs and issued a warning about 75 dangerous brands which contain

methanol used in antifreeze and can cause death, kidney damage and blindness. The FDA circulated the following warning even for those brands that it claims to be safe:

Store hand sanitizer out of the reach of pets and children, and children should use it only with adult supervision. Do not drink hand sanitizer. This is particularly important for young children, especially toddlers, who may be attracted by the pleasant smell or brightly colored bottles of hand sanitizer.

Drinking even a small amount of hand sanitizer can cause alcohol poisoning in children. (However, there is no need to be concerned if your children eat with or lick their hands after using hand sanitizer.) During this coronavirus pandemic, poison control centers have had an increase in calls about accidental ingestion of hand sanitizer, so it is important that adults monitor young children's use.

Do not allow pets to swallow hand sanitizer. If you think your pet has eaten something potentially dangerous, call your veterinarian or a pet poison control center right away. Hand sanitizer is flammable and should be stored away from heat and flames. When using hand sanitizer, rub your hands until they feel completely dry before performing activities that may involve heat, sparks, static electricity, or open flames.

There you go, perfectly safe, then, and that's without even a mention of the toxins absorbed through the skin. Come on kids – sanitise your hands everywhere you go. It will save you from the 'virus'. Put all these elements together of the 'Covid' normal and see how much health and psychology is being cumulatively damaged, even devastated, to 'protect your health'. Makes sense, right? They are only imposing these things because they care, right? *Right?*

Submitting to insanity

Psychological reframing of the population goes very deep and is done in many less obvious ways. I hear people say how contradictory and crazy 'Covid' rules are and how they are ever changing. This is explained away by dismissing those involved as idiots. It is a big mistake. The Cult is delighted if its cold calculation is perceived as incompetence and idiocy when it is anything but. Oh, yes, there are idiots within the system – lots of them – but they are *administering* the Cult agenda, mostly unknowingly. They are not deciding and dictating it. The bulwark against tyranny is self-

respect, always has been, always will be. It is self-respect that has broken every tyranny in history. By its very nature self-respect will not bow to oppression and its perpetrators. There is so little self-respect that it's always the few that overturn dictators. Many may eventually follow, but the few with the iron spines (self-respect) kick it off and generate the momentum. The Cult targets self-respect in the knowledge that once this has gone only submission remains. Crazy, contradictory, ever-changing 'Covid' rules are systematically applied by psychologists to delete self-respect. They *want* you to see that the rules make no sense. It is one thing to decide to do something when *you* have made the choice based on evidence and logic. You still retain your self-respect. It is quite another when you can see what you are being told to do is insane, ridiculous and makes no sense, and *yet you still do it*. Your self-respect is extinguished and this has been happening as ever more obviously stupid and nonsensical things have been demanded and the great majority have complied even when they can see they are stupid and nonsensical.

People walk around in face-nappies knowing they are damaging their health and make no difference to a 'virus'. They do it in fear of not doing it. I know it's daft, but I'll do it anyway. When that happens something dies inside of you and submissive reframing has begun. Next there's a need to hide from yourself that you have conceded your self-respect and you convince yourself that you have not really submitted to fear and intimidation. You begin to believe that you are complying with craziness because it's the right thing to do. When first you concede your self-respect of 2+2 = 4 to 2+2 = 5 you *know* you are compromising your self-respect. Gradually to avoid facing that fact you begin to *believe* that 2+2=5. You have been reframed and I have been watching this process happening in the human psyche on an industrial scale. The Cult is working to break your spirit and one of its major tools in that war is humiliation. I read how former American soldier Bradley Manning (later Chelsea Manning after a sex-change) was treated after being jailed for supplying WikiLeaks with documents exposing the enormity of

government and elite mendacity. Manning was isolated in solitary confinement for eight months, put under 24-hour surveillance, forced to hand over clothing before going to bed, and stand naked for every roll call. This is systematic humiliation. The introduction of anal swab 'Covid' tests in China has been done for the same reason to delete self-respect and induce compliant submission. Anal swabs are mandatory for incoming passengers in parts of China and American diplomats have said they were forced to undergo the indignity which would have been calculated humiliation by the Cult-owned Chinese government that has America in its sights.

Government-people: An abusive relationship

Spirit-breaking psychological techniques include giving people hope and apparent respite from tyranny only to take it away again. This happened in the UK during Christmas, 2020, when the psycho-psychologists and their political lackeys announced an easing of restrictions over the holiday only to reimpose them almost immediately on the basis of yet another lie. There is a big psychological difference between getting used to oppression and being given hope of relief only to have that dashed. Psychologists know this and we have seen the technique used repeatedly. Then there is traumatising people before you introduce more extreme regulations that require compliance. A perfect case was the announcement by the dark and sinister Whitty and Vallance in the UK that 'new data' predicted that 4,000 could die every day over the winter of 2020/2021 if we did not lockdown again. I think they call it lying and after traumatising people with that claim out came Jackboot Johnson the next day with new curbs on human freedom. Psychologists know that a frightened and traumatised mind becomes suggestable to submission and behaviour reframing. Underpinning all this has been to make people fearful and suspicious of each other and see themselves as a potential danger to others. In league with deleted self-respect you have the perfect psychological recipe for self-loathing. The relationship between authority and public is now demonstrably the same as that of

subservience to an abusive partner. These are signs of an abusive relationship explained by psychologist Leslie Becker-Phelps:

Psychological and emotional abuse: Undermining a partner's self-worth with verbal attacks, name-calling, and belittling. Humiliating the partner in public, unjustly accusing them of having an affair, or interrogating them about their every behavior. Keeping partner confused or off balance by saying they were just kidding or blaming the partner for 'making' them act this way … Feigning in public that they care while turning against them in private. This leads to victims frequently feeling confused, incompetent, unworthy, hopeless, and chronically self-doubting. [Apply these techniques to how governments have treated the population since New Year, 2020, and the parallels are obvious.]

Physical abuse: The abuser might physically harm their partner in a range of ways, such as grabbing, hitting, punching, or shoving them. They might throw objects at them or harm them with a weapon. [Observe the physical harm imposed by masks, lockdown, and so on.]

Threats and intimidation: One way abusers keep their partners in line is by instilling fear. They might be verbally threatening, or give threatening looks or gestures. Abusers often make it known that they are tracking their partner's every move. They might destroy their partner's possessions, threaten to harm them, or threaten to harm their family members. Not surprisingly, victims of this abuse often feel anxiety, fear, and panic. [No words necessary.]

Isolation: Abusers often limit their partner's activities, forbidding them to talk or interact with friends or family. They might limit access to a car or even turn off their phone. All of this might be done by physically holding them against their will, but is often accomplished through psychological abuse and intimidation. The more isolated a person feels, the fewer resources they have to help gain perspective on their situation and to escape from it. [No words necessary.]

Economic abuse: Abusers often make their partners beholden to them for money by controlling access to funds of any kind. They might prevent their partner from getting a job or withhold access to money they earn from a job. This creates financial dependency that makes leaving the relationship very difficult. [See destruction of livelihoods and the proposed meagre 'guaranteed income' so long as you do whatever you are told.]

Using children: An abuser might disparage their partner's parenting skills, tell their children lies about their partner, threaten to take custody of their children, or threaten to harm their children. These tactics instil fear and often elicit compliance. [See reframed social service mafia and how children are being mercilessly abused by the state over 'Covid' while their parents look on too frightened to do anything.]

A further recurring trait in an abusive relationship is the abused blaming themselves for their abuse and making excuses for the abuser. We have the public blaming each other for lockdown abuse by government and many making excuses for the government while attacking those who challenge the government. How often we have heard authorities say that rules are being imposed or reimposed only because people have refused to 'behave' and follow the rules. We don't want to do it – it's *you*.

Renegade Minds are an antidote to all of these things. They will never concede their self-respect no matter what the circumstances. Even when apparent humiliation is heaped upon them they laugh in its face and reflect back the humiliation on the abuser where it belongs. Renegade Minds will never wear masks they know are only imposed to humiliate, suppress and damage both physically and psychologically. Consequences will take care of themselves and they will never break their spirit or cause them to concede to tyranny. UK newspaper columnist Peter Hitchens was one of the few in the mainstream media to speak out against lockdowns and forced vaccinations. He then announced he had taken the jab. He wanted to see family members abroad and he believed vaccine passports were inevitable even though they had not yet been introduced. Hitchens

has a questioning and critical mind, but not a Renegade one. If he had no amount of pressure would have made him concede. Hitchens excused his action by saying that the battle has been lost. Renegade Minds never accept defeat when freedom is at stake and even if they are the last one standing the self-respect of not submitting to tyranny is more important than any outcome or any consequence.

That's why Renegade Minds are the only minds that ever changed anything worth changing.

CHAPTER EIGHT

'Reframing' insanity

Insanity is relative. It depends on who has who locked in what cage
Ray Bradbury

'Reframing' a mind means simply to change its perception and behaviour. This can be done subconsciously to such an extent that subjects have no idea they have been 'reframed' while to any observer changes in behaviour and attitudes are obvious.

Human society is being reframed on a ginormous scale since the start of 2020 and here we have the reason why psychologists rather than doctors have been calling the shots. Ask most people who have succumbed to 'Covid' reframing if they have changed and most will say 'no'; but they *have* and fundamentally. The Cult's long-game has been preparing for these times since way back and crucial to that has been to prepare both population and officialdom mentally and emotionally. To use the mind-control parlance they had to reframe the population with a mentality that would submit to fascism and reframe those in government and law enforcement to impose fascism or at least go along with it. The result has been the fact-deleted mindlessness of 'Wokeness' and officialdom that has either enthusiastically or unquestioningly imposed global tyranny demanded by reframed politicians on behalf of psychopathic and deeply evil cultists. 'Cognitive reframing' identifies and challenges the way someone sees the world in the form of situations, experiences and emotions and then restructures those perceptions to view the same set of circumstances in a different way. This can have

benefits if the attitudes are personally destructive while on the other side it has the potential for individual and collective mind control which the subject has no idea has even happened.

Cognitive therapy was developed in the 1960s by Aaron T. Beck who was born in Rhode Island in 1921 as the son of Jewish immigrants from the Ukraine. He became interested in the techniques as a treatment for depression. Beck's daughter Judith S. Beck is prominent in the same field and they founded the Beck Institute for Cognitive Behavior Therapy in Philadelphia in 1994. Cognitive reframing, however, began to be used worldwide by those with a very dark agenda. The Cult reframes politicians to change their attitudes and actions until they are completely at odds with what they once appeared to stand for. The same has been happening to government administrators at all levels, law enforcement, military and the human population. Cultists love mind control for two main reasons: It allows them to control what people think, do and say to secure agenda advancement and, by definition, it calms their legendary insecurity and fear of the unexpected. I have studied mind control since the time I travelled America in 1996. I may have been talking to next to no one in terms of an audience in those years, but my goodness did I gather a phenomenal amount of information and knowledge about so many things including the techniques of mind control. I have described this in detail in other books going back to *The Biggest Secret* in 1998. I met a very large number of people recovering from MKUltra and its offshoots and successors and I began to see how these same techniques were being used on the population in general. This was never more obvious than since the 'Covid' hoax began.

Reframing the enforcers

I have observed over the last two decades and more the very clear transformation in the dynamic between the police, officialdom and the public. I tracked this in the books as the relationship mutated from one of serving the public to seeing them as almost the enemy and certainly a lower caste. There has always been a class divide

based on income and always been some psychopathic, corrupt, and big-I-am police officers. This was different. Wholesale change was unfolding in the collective dynamic; it was less about money and far more about position and perceived power. An us-and-them was emerging. Noses were lifted skyward by government administration and law enforcement and their attitude to the public they were *supposed* to be serving changed to one of increasing contempt, superiority and control. The transformation was so clear and widespread that it had to be planned. Collective attitudes and dynamics do not change naturally and organically that quickly on that scale. I then came across an organisation in Britain called Common Purpose created in the late 1980s by Julia Middleton who would work in the office of Deputy Prime Minister John Prescott during the long and disastrous premiership of war criminal Tony Blair. When Blair speaks the Cult is speaking and the man should have been in jail a long time ago. Common Purpose proclaims itself to be one of the biggest 'leadership development' organisations in the world while functioning as a *charity* with all the financial benefits which come from that. It hosts 'leadership development' courses and programmes all over the world and claims to have 'brought together' what it calls 'leaders' from more than 100 countries on six continents. The modus operandi of Common Purpose can be compared with the work of the UK government's reframing network that includes the Behavioural Insights Team 'nudge unit' and 'Covid' reframing specialists at SPI-B. WikiLeaks described Common Purpose long ago as 'a hidden virus in our government and schools' which is unknown to the general public: 'It recruits and trains "leaders" to be loyal to the directives of Common Purpose and the EU, instead of to their own departments, which they then undermine or subvert, the NHS [National Health Service] being an example.' This is a vital point to understand the 'Covid' hoax. The NHS, and its equivalent around the world, has been utterly reframed in terms of administrators and much of the medical personnel with the transformation underpinned by recruitment policies. The outcome has been the criminal and psychopathic behaviour of the

NHS over 'Covid' and we have seen the same in every other major country. WikiLeaks said Common Purpose trainees are 'learning to rule without regard to democracy' and to usher in a police state (current events explained). Common Purpose operated like a 'glue' and had members in the NHS, BBC, police, legal profession, church, many of Britain's 7,000 quangos, local councils, the Civil Service, government ministries and Parliament, and controlled many RDA's (Regional Development Agencies). Here we have one answer for how and why British institutions and their like in other countries have changed so negatively in relation to the public. This further explains how and why the beyond-disgraceful reframed BBC has become a propaganda arm of 'Covid' fascism. They are all part of a network pursuing the same goal.

By 2019 Common Purpose was quoting a figure of 85,000 'leaders' that had attended its programmes. These 'students' of all ages are known as Common Purpose 'graduates' and they consist of government, state and local government officials and administrators, police chiefs and officers, and a whole range of others operating within the national, local and global establishment. Cressida Dick, Commissioner of the London Metropolitan Police, is the Common Purpose graduate who was the 'Gold Commander' that oversaw what can only be described as the murder of Brazilian electrician Jean Charles de Menezes in 2005. He was held down by psychopathic police and shot seven times in the head by a psychopathic lunatic after being mistaken for a terrorist when he was just a bloke going about his day. Dick authorised officers to pursue and keep surveillance on de Menezes and ordered that he be stopped from entering the underground train system. Police psychopaths took her at her word clearly. She was 'disciplined' for this outrage by being *promoted* – eventually to the top of the 'Met' police where she has been a disaster. Many Chief Constables controlling the police in different parts of the UK are and have been Common Purpose graduates. I have heard the 'graduate' network described as a sort of Mafia or secret society operating within the fabric of government at all levels pursuing a collective policy

ingrained at Common Purpose training events. Founder Julia Middleton herself has said:

> Locally and internationally, Common Purpose graduates will be 'lighting small fires' to create change in their organisations and communities … The Common Purpose effect is best illustrated by the many stories of small changes brought about by leaders, who themselves have changed.

A Common Purpose mission statement declared:

> Common Purpose aims to improve the way society works by expanding the vision, decision-making ability and influence of all kinds of leaders. The organisation runs a variety of educational programmes for leaders of all ages, backgrounds and sectors, in order to provide them with the inspirational, information and opportunities they need to change the world.

Yes, but into what? Since 2020 the answer has become clear.

NLP and the Delphi technique

Common Purpose would seem to be a perfect name or would common programming be better? One of the foundation methods of reaching 'consensus' (group think) is by setting the agenda theme and then encouraging, cajoling or pressuring everyone to agree a 'consensus' in line with the core theme promoted by Common Purpose. The methodology involves the 'Delphi technique', or an adaption of it, in which opinions are expressed that are summarised by a 'facilitator or change agent' at each stage. Participants are 'encouraged' to modify their views in the light of what others have said. Stage by stage the former individual opinions are merged into group consensus which just happens to be what Common Purpose wants them to believe. A key part of this is to marginalise anyone refusing to concede to group think and turn the group against them to apply pressure to conform. We are seeing this very technique used on the general population to make 'Covid' group-thinkers hostile to those who have seen through the bullshit. People can be reframed by using perception manipulation methods such as Neuro-Linguistic Programming (NLP) in which you change perception with the use of

carefully constructed language. An NLP website described the technique this way:

… A method of influencing brain behaviour (the 'neuro' part of the phrase) through the use of language (the 'linguistic' part) and other types of communication to enable a person to 'recode' the way the brain responds to stimuli (that's the 'programming') and manifest new and better behaviours. Neuro-Linguistic Programming often incorporates hypnosis and self-hypnosis to help achieve the change (or 'programming') that is wanted.

British alternative media operation UKColumn has done very detailed research into Common Purpose over a long period. I quoted co-founder and former naval officer Brian Gerrish in my book *Remember Who You Are*, published in 2011, as saying the following years before current times:

It is interesting that many of the mothers who have had children taken by the State speak of the Social Services people being icily cool, emotionless and, as two ladies said in slightly different words, '… like little robots'. We know that NLP is cumulative, so people can be given small imperceptible doses of NLP in a course here, another in a few months, next year etc. In this way, major changes are accrued in their personality, but the day by day change is almost unnoticeable.

In these and other ways 'graduates' have had their perceptions uniformly reframed and they return to their roles in the institutions of government, law enforcement, legal profession, military, 'education', the UK National Health Service and the whole swathe of the establishment structure to pursue a common agenda preparing for the 'post-industrial', 'post-democratic' society. I say 'preparing' but we are now there. 'Post-industrial' is code for the Great Reset and 'post-democratic' is 'Covid' fascism. UKColumn has spoken to partners of those who have attended Common Purpose 'training'. They have described how personalities and attitudes of 'graduates' changed very noticeably for the worse by the time they had completed the course. They had been 'reframed' and told they are the 'leaders' – the special ones – who know better than the population. There has also been the very demonstrable recruitment of psychopaths and narcissists into government administration at all

levels and law enforcement. If you want psychopathy hire psychopaths and you get a simple cause and effect. If you want administrators, police officers and 'leaders' to perceive the public as lesser beings who don't matter then employ narcissists. These personalities are identified using 'psychometrics' that identifies knowledge, abilities, attitudes and personality traits, mostly through carefully-designed questionnaires and tests. As this policy has passed through the decades we have had power-crazy, power-trippers appointed into law enforcement, security and government administration in preparation for current times and the dynamic between public and law enforcement/officialdom has been transformed. UKColumn's Brian Gerrish said of the narcissistic personality:

> Their love of themselves and power automatically means that they will crush others who get in their way. I received a major piece of the puzzle when a friend pointed out that when they made public officials re-apply for their own jobs several years ago they were also required to do psychometric tests. This was undoubtedly the start of the screening process to get 'their' sort of people in post.

How obvious that has been since 2020 although it was clear what was happening long before if people paid attention to the changing public-establishment dynamic.

Change agents

At the centre of events in 'Covid' Britain is the National Health Service (NHS) which has behaved disgracefully in slavishly following the Cult agenda. The NHS management structure is awash with Common Purpose graduates or 'change agents' working to a common cause. Helen Bevan, a Chief of Service Transformation at the NHS Institute for Innovation and Improvement, co-authored a document called 'Towards a million change agents, a review of the social movements literature: implications for large scale change in the NHS'. The document compared a project management approach to that of change and social movements where 'people change

themselves and each other – peer to peer'. Two definitions given for a 'social movement' were:

A group of people who consciously attempt to build a radically new social order; involves people of a broad range of social backgrounds; and deploys politically confrontational and socially disruptive tactics – Cyrus Zirakzadeh 1997

Collective challenges, based on common purposes and social solidarities, in sustained interaction with elites, opponents, and authorities – Sidney Tarrow 1994

Helen Bevan wrote another NHS document in which she defined 'framing' as 'the process by which leaders construct, articulate and put across their message in a powerful and compelling way in order to win people to their cause and call them to action'. I think I could come up with another definition that would be rather more accurate. The National Health Service and institutions of Britain and the wider world have been taken over by reframed 'change agents' and that includes everything from the United Nations to national governments, local councils and social services which have been kidnapping children from loving parents on an extraordinary and gathering scale on the road to the end of parenthood altogether. Children from loving homes are stolen and kidnapped by the state and put into the 'care' (inversion) of the local authority through council homes, foster parents and forced adoption. At the same time children are allowed to be abused without response while many are under council 'care'. UKColumn highlighted the Common Purpose connection between South Yorkshire Police and Rotherham council officers in the case of the scandal in that area of the sexual exploitation of children to which the authorities turned not one blind eye, but both:

We were alarmed to discover that the Chief Executive, the Strategic Director of Children and Young People's Services, the Manager for the Local Strategic Partnership, the Community Cohesion Manager, the Cabinet Member for Cohesion, the Chief Constable and his predecessor had all attended Leadership training courses provided by the pseudo-charity Common Purpose.

Once 'change agents' have secured positions of hire and fire within any organisation things start to move very quickly. Personnel are then hired and fired on the basis of whether they will work towards the agenda the change agent represents. If they do they are rapidly promoted even though they may be incompetent. Those more qualified and skilled who are pre-Common Purpose 'old school' see their careers stall and even disappear. This has been happening for decades in every institution of state, police, 'health' and social services and all of them have been transformed as a result in their attitudes to their jobs and the public. Medical professions, including nursing, which were once vocations for the caring now employ many cold, callous and couldn't give a shit personality types. The UKColumn investigation concluded:

By blurring the boundaries between people, professions, public and private sectors, responsibility and accountability, Common Purpose encourages 'graduates' to believe that as new selected leaders, they can work together, outside of the established political and social structures, to achieve a paradigm shift or CHANGE – so called 'Leading Beyond Authority'. In doing so, the allegiance of the individual becomes 'reframed' on CP colleagues and their NETWORK.

Reframing the Face-Nappies

Nowhere has this process been more obvious than in the police where recruitment of psychopaths and development of unquestioning mind-controlled group-thinkers have transformed law enforcement into a politically-correct 'Woke' joke and a travesty of what should be public service. Today they wear their face-nappies like good little gofers and enforce 'Covid' rules which are fascism under another name. Alongside the specifically-recruited psychopaths we have software minds incapable of free thought. Brian Gerrish again:

An example is the policeman who would not get on a bike for a press photo because he had not done the cycling proficiency course. Normal people say this is political correctness gone mad. Nothing could be further from the truth. The policeman has been reframed, and in his reality it is perfect common sense not to get on the bike 'because he hasn't done the cycling course'.

Another example of this is where the police would not rescue a boy from a pond until they had taken advice from above on the 'risk assessment'. A normal person would have arrived, perhaps thought of the risk for a moment, and dived in. To the police now 'reframed', they followed 'normal' procedure.

There are shocking cases of reframed ambulance crews doing the same. Sheer unthinking stupidity of London Face-Nappies headed by Common Purpose graduate Cressida Dick can be seen in their behaviour at a vigil in March, 2021, for a murdered woman, Sarah Everard. A police officer had been charged with the crime. Anyone with a brain would have left the vigil alone in the circumstances. Instead they 'manhandled' women to stop them breaking 'Covid rules' to betray classic reframing. Minds in the thrall of perception control have no capacity for seeing a situation on its merits and acting accordingly. 'Rules is rules' is their only mind-set. My father used to say that rules and regulations are for the guidance of the intelligent and the blind obedience of the idiot. Most of the intelligent, decent, coppers have gone leaving only the other kind and a few old school for whom the job must be a daily nightmare. The combination of psychopaths and rule-book software minds has been clearly on public display in the 'Covid' era with automaton robots in uniform imposing fascistic 'Covid' regulations on the population without any personal initiative or judging situations on their merits. There are thousands of examples around the world, but I'll make my point with the infamous Derbyshire police in the English East Midlands – the ones who think pouring dye into beauty spots and using drones to track people walking in the countryside away from anyone is called 'policing'. To them there are rules decreed by the government which they have to enforce and in their bewildered state a group gathering in a closed space and someone walking alone in the countryside are the same thing. It is beyond idiocy and enters the realm of clinical insanity.

Police officers in Derbyshire said they were 'horrified' – *horrified* – to find 15 to 20 'irresponsible' kids playing a football match at a closed leisure centre 'in breach of coronavirus restrictions'. When they saw the police the kids ran away leaving their belongings behind and the reframed men and women of Derbyshire police were seeking to establish their identities with a view to fining their parents. The most natural thing for youngsters to do – kicking a ball about – is turned into a criminal activity and enforced by the moronic software programs of Derbyshire police. You find the same mentality in every country. These barely conscious 'horrified' officers said they had to take action because 'we need to ensure these rules are being followed' and 'it is of the utmost importance that you ensure your children are following the rules and regulations for Covid-19'. Had any of them done ten seconds of research to see if this parroting of their masters' script could be supported by any evidence? Nope. Reframed people don't think – others think for them and that's the whole idea of reframing. I have seen police officers one after the other repeating without question word for word what officialdom tells them just as I have seen great swathes of the public doing the same. Ask either for 'their' opinion and out spews what they have been told to think by the official narrative. Police and public may seem to be in different groups, but their mentality is the same. Most people do whatever they are told in fear not doing so or because they believe what officialdom tells them; almost the entirety of the police do what they are told for the same reason. Ultimately it's the tiny inner core of the global Cult that's telling both what to do.

So Derbyshire police were 'horrified'. Oh, really? Why did they think those kids were playing football? It was to relieve the psychological consequences of lockdown and being denied human contact with their friends and interaction, touch and discourse vital to human psychological health. Being denied this month after month has dismantled the psyche of many children and young people as depression and suicide have exploded. Were Derbyshire police *horrified by that*? Are you kidding? Reframed people don't have those

mental and emotional processes that can see how the impact on the psychological health of youngsters is far more dangerous than any 'virus' even if you take the mendacious official figures to be true. The reframed are told (programmed) how to act and so they do. The Derbyshire Chief Constable in the first period of lockdown when the black dye and drones nonsense was going on was Peter Goodman. He was the man who severed the connection between his force and the Derbyshire Constabulary *Male Voice* Choir when he decided that it was not inclusive enough to allow women to join. The fact it was a male voice choir making a particular sound produced by male voices seemed to elude a guy who terrifyingly ran policing in Derbyshire. He retired weeks after his force was condemned as disgraceful by former Supreme Court Justice Jonathan Sumption for their behaviour over extreme lockdown impositions. Goodman was replaced by his deputy Rachel Swann who was in charge when her officers were 'horrified'. The police statement over the boys committing the hanging-offence of playing football included the line about the youngsters being 'irresponsible in the times we are all living through' missing the point that the real relevance of the 'times we are all living through' is the imposition of fascism enforced by psychopaths and reframed minds of police officers playing such a vital part in establishing the fascist tyranny that their own children and grandchildren will have to live in their entire lives. As a definition of insanity that is hard to beat although it might be run close by imposing masks on people that can have a serious effect on their health while wearing a face nappy all day themselves. Once again public and police do it for the same reason – the authorities tell them to and who are they to have the self-respect to say no?

Wokers in uniform

How reframed do you have to be to arrest a *six-year-old* and take him to court for *picking a flower* while waiting for a bus? Brain dead police and officialdom did just that in North Carolina where criminal proceedings happen regularly for children under nine. Attorney Julie Boyer gave the six-year-old crayons and a colouring book

during the 'flower' hearing while the 'adults' decided his fate. County Chief District Court Judge Jay Corpening asked: 'Should a child that believes in Santa Claus, the Easter Bunny and the tooth fairy be making life-altering decisions?' Well, of course not, but common sense has no meaning when you have a common purpose and a reframed mind. Treating children in this way, and police operating in American schools, is all part of the psychological preparation for children to accept a police state as normal all their adult lives. The same goes for all the cameras and biometric tracking technology in schools. Police training is focused on reframing them as snowflake Wokers and this is happening in the military. Pentagon top brass said that 'training sessions on extremism' were needed for troops who asked why they were so focused on the Capitol Building riot when Black Lives Matter riots were ignored. What's the difference between them some apparently and rightly asked. Actually, there is a difference. Five people died in the Capitol riot, only one through violence, and that was a police officer shooting an unarmed protestor. BLM riots killed at least 25 people and cost billions. Asking the question prompted the psychopaths and reframed minds that run the Pentagon to say that more 'education' (programming) was needed. Troop training is all based on psychological programming to make them fodder for the Cult – 'Military men are just dumb, stupid animals to be used as pawns in foreign policy' as Cult-to-his-DNA former Secretary of State Henry Kissinger famously said. Governments see the police in similar terms and it's time for those among them who can see this to defend the people and stop being enforcers of the Cult agenda upon the people.

The US military, like the country itself, is being targeted for destruction through a long list of Woke impositions. Cult-owned gaga 'President' Biden signed an executive order when he took office to allow taxpayer money to pay for transgender surgery for active military personnel and veterans. Are you a man soldier? No, I'm a LGBTQIA+ with a hint of Skoliosexual and Spectrasexual. Oh, good man. Bad choice of words you bigot. The Pentagon announced in March, 2021, the appointment of the first 'diversity and inclusion

officer' for US Special Forces. Richard Torres-Estrada arrived with the publication of a 'D&I Strategic Plan which will guide the enterprise-wide effort to institutionalize and sustain D&I'. If you think a Special Forces 'Strategic Plan' should have something to do with defending America you haven't been paying attention. Defending Woke is now the military's new role. Torres-Estrada has posted images comparing Donald Trump with Adolf Hitler and we can expect no bias from him as a representative of the supposedly non-political Pentagon. Cable news host Tucker Carlson said: 'The Pentagon is now the Yale faculty lounge but with cruise missiles.' Meanwhile Secretary of Defense Lloyd Austin, a board member of weapons-maker Raytheon with stock and compensation interests in October, 2020, worth $1.4 million, said he was purging the military of the 'enemy within' – anyone who isn't Woke and supports Donald Trump. Austin refers to his targets as 'racist extremists' while in true Woke fashion being himself a racist extremist. Pentagon documents pledge to 'eradicate, eliminate and conquer all forms of racism, sexism and homophobia'. The definitions of these are decided by 'diversity and inclusion committees' peopled by those who see racism, sexism and homophobia in every situation and opinion. Woke (the Cult) is dismantling the US military and purging testosterone as China expands its military and gives its troops 'masculinity training'. How do we think that is going to end when this is all Cult coordinated? The US military, like the British military, is controlled by Woke and spineless top brass who just go along with it out of personal career interests.

'Woke' means fast asleep

Mind control and perception manipulation techniques used on individuals to create group-think have been unleashed on the global population in general. As a result many have no capacity to see the obvious fascist agenda being installed all around them or what 'Covid' is really all about. Their brains are firewalled like a computer system not to process certain concepts, thoughts and realisations that are bad for the Cult. The young are most targeted as the adults they

will be when the whole fascist global state is planned to be fully implemented. They need to be prepared for total compliance to eliminate all pushback from entire generations. The Cult has been pouring billions into taking complete control of 'education' from schools to universities via its operatives and corporations and not least Bill Gates as always. The plan has been to transform 'education' institutions into programming centres for the mentality of 'Woke'. James McConnell, professor of psychology at the University of Michigan, wrote in *Psychology Today* in 1970:

> The day has come when we can combine sensory deprivation with drugs, hypnosis, and astute manipulation of reward and punishment, to gain almost absolute control over an individual's behaviour. It should then be possible to achieve a very rapid and highly effective type of brainwashing that would allow us to make dramatic changes in a person's behaviour and personality ...
>
> … We should reshape society so that we all would be trained from birth to want to do what society wants us to do. We have the techniques to do it... no-one owns his own personality you acquired, and there's no reason to believe you should have the right to refuse to acquire a new personality if your old one is anti-social.

This was the potential for mass brainwashing in 1970 and the mentality there displayed captures the arrogant psychopathy that drives it forward. I emphasise that not all young people have succumbed to Woke programming and those that haven't are incredibly impressive people given that today's young are the most perceptually-targeted generations in history with all the technology now involved. Vast swathes of the young generations, however, have fallen into the spell – and that's what it is – of Woke. The Woke mentality and perceptual program is founded on *inversion* and you will appreciate later why that is so significant. Everything with Woke is inverted and the opposite of what it is claimed to be. Woke was a term used in African-American culture from the 1900s and referred to an awareness of social and racial justice. This is not the meaning of the modern version or 'New Woke' as I call it in *The Answer*. Oh, no, Woke today means something very different no matter how much Wokers may seek to hide that and insist Old Woke and New

Woke are the same. See if you find any 'awareness of social justice' here in the modern variety:

- Woke demands 'inclusivity' while excluding anyone with a different opinion and calls for mass censorship to silence other views.

- Woke claims to stand against oppression when imposing oppression is the foundation of all that it does. It is the driver of political correctness which is nothing more than a Cult invention to manipulate the population to silence itself.

- Woke believes itself to be 'liberal' while pursuing a global society that can only be described as fascist (see 'anti-fascist' fascist Antifa).

- Woke calls for 'social justice' while spreading injustice wherever it goes against the common 'enemy' which can be easily identified as a differing view.

- Woke is supposed to be a metaphor for 'awake' when it is solid-gold asleep and deep in a Cult-induced coma that meets the criteria for 'off with the fairies'.

I state these points as obvious facts if people only care to look. I don't do this with a sense of condemnation. We need to appreciate that the onslaught of perceptual programming on the young has been incessant and merciless. I can understand why so many have been reframed, or, given their youth, framed from the start to see the world as the Cult demands. The Cult has had access to their minds day after day in its 'education' system for their entire formative years. Perception is formed from information received and the Cult-created system is a life-long download of information delivered to elicit a particular perception, thus behaviour. The more this has expanded into still new extremes in recent decades and ever-increasing censorship has deleted other opinions and information why wouldn't that lead to a perceptual reframing on a mass scale? I

have described already cradle-to-grave programming and in more recent times the targeting of young minds from birth to adulthood has entered the stratosphere. This has taken the form of skewing what is 'taught' to fit the Cult agenda and the omnipresent techniques of group-think to isolate non-believers and pressure them into line. There has always been a tendency to follow the herd, but we really are in a new world now in relation to that. We have parents who can see the 'Covid' hoax told by their children not to stop them wearing masks at school, being 'Covid' tested or having the 'vaccine' in fear of the peer-pressure consequences of being different. What is 'peer-pressure' if not pressure to conform to group-think? Renegade Minds never group-think and always retain a set of perceptions that are unique to them. Group-think is always underpinned by consequences for not group-thinking. Abuse now aimed at those refusing DNA-manipulating 'Covid vaccines' are a potent example of this. The biggest pressure to conform comes from the very group which is itself being manipulated. 'I am programmed to be part of a hive mind and so you must be.'

Woke control structures in 'education' now apply to every mainstream organisation. Those at the top of the 'education' hierarchy (the Cult) decide the policy. This is imposed on governments through the Cult network; governments impose it on schools, colleges and universities; their leadership impose the policy on teachers and academics and they impose it on children and students. At any level where there is resistance, perhaps from a teacher or university lecturer, they are targeted by the authorities and often fired. Students themselves regularly demand the dismissal of academics (increasingly few) at odds with the narrative that the students have been programmed to believe in. It is quite a thought that students who are being targeted by the Cult become so consumed by programmed group-think that they launch protests and demand the removal of those who are trying to push back against those targeting the students. Such is the scale of perceptual inversion. We see this with 'Covid' programming as the Cult imposes the rules via psycho-psychologists and governments on

shops, transport companies and businesses which impose them on their staff who impose them on their customers who pressure Pushbackers to conform to the will of the Cult which is in the process of destroying them and their families. Scan all aspects of society and you will see the same sequence every time.

Fact free Woke and hijacking the 'left'

There is no more potent example of this than 'Woke', a mentality only made possible by the deletion of factual evidence by an 'education' system seeking to produce an ever more uniform society. Why would you bother with facts when you don't know any? Deletion of credible history both in volume and type is highly relevant. Orwell said: 'Who controls the past controls the future: who controls the present controls the past.' They who control the perception of the past control the perception of the future and they who control the present control the perception of the past through the writing and deleting of history. Why would you oppose the imposition of Marxism in the name of Wokeism when you don't know that Marxism cost at least 100 million lives in the 20th century alone? Watch videos and read reports in which Woker generations are asked basic historical questions – it's mind-blowing. A survey of 2,000 people found that six percent of millennials (born approximately early1980s to early 2000s) believed the Second World War (1939-1945) broke out with the assassination of President Kennedy (in 1963) and one in ten thought Margaret Thatcher was British Prime Minister at the time. She was in office between 1979 and 1990. We are in a post-fact society. Provable facts are no defence against the fascism of political correctness or Silicon Valley censorship. Facts don't matter anymore as we have witnessed with the 'Covid' hoax. Sacrificing uniqueness to the Woke group-think religion is all you are required to do and that means thinking for yourself is the biggest Woke no, no. All religions are an expression of group-think and censorship and Woke is just another religion with an orthodoxy defended by group-think and censorship. Burned at

the stake becomes burned on Twitter which leads back eventually to burned at the stake as Woke humanity regresses to ages past.

The biggest Woke inversion of all is its creators and funders. I grew up in a traditional left of centre political household on a council estate in Leicester in the 1950s and 60s – you know, the left that challenged the power of wealth-hoarding elites and threats to freedom of speech and opinion. In those days students went on marches defending freedom of speech while today's Wokers march for its deletion. What on earth could have happened? Those very elites (collectively the Cult) that we opposed in my youth and early life have funded into existence the antithesis of that former left and hijacked the 'brand' while inverting everything it ever stood for. We have a mentality that calls itself 'liberal' and 'progressive' while acting like fascists. Cult billionaires and their corporations have funded themselves into control of 'education' to ensure that Woke programming is unceasing throughout the formative years of children and young people and that non-Wokers are isolated (that word again) whether they be students, teachers or college professors. The Cult has funded into existence the now colossal global network of Woke organisations that have spawned and promoted all the 'causes' on the Cult wish-list for global transformation and turned Wokers into demanders of them. Does anyone really think it's a coincidence that the Cult agenda for humanity is a carbon (sorry) copy of the societal transformations desired by Woke?? These are only some of them:

Political correctness: The means by which the Cult deletes all public debates that it knows it cannot win if we had the free-flow of information and evidence.

Human-caused 'climate change': The means by which the Cult seeks to transform society into a globally-controlled dictatorship imposing its will over the fine detail of everyone's lives 'to save the planet' which doesn't actually need saving.

Transgender obsession: Preparing collective perception to accept the 'new human' which would not have genders because it would be created technologically and not through procreation. I'll have much more on this in Human 2.0.

Race obsession: The means by which the Cult seeks to divide and rule the population by triggering racial division through the perception that society is more racist than ever when the opposite is the case. Is it perfect in that regard? No. But to compare today with the racism of apartheid and segregation brought to an end by the civil rights movement in the 1960s is to insult the memory of that movement and inspirations like Martin Luther King. Why is the 'anti-racism' industry (which it is) so dominated by privileged white people?

White supremacy: This is a label used by privileged white people to demonise poor and deprived white people pushing back on tyranny to marginalise and destroy them. White people are being especially targeted as the dominant race by number within Western society which the Cult seeks to transform in its image. If you want to change a society you must weaken and undermine its biggest group and once you have done that by using the other groups you next turn on them to do the same … 'Then they came for the Jews and I was not a Jew so I did nothing.'

Mass migration: The mass movement of people from the Middle East, Africa and Asia into Europe, from the south into the United States and from Asia into Australia are another way the Cult seeks to dilute the racial, cultural and political influence of white people on Western society. White people ask why their governments appear to be working against them while being politically and culturally biased towards incoming cultures. Well, here's your answer. In the same way sexually 'straight' people, men and women, ask why the

authorities are biased against them in favour of other sexualities. The answer is the same – that's the way the Cult wants it to be for very sinister motives.

These are all central parts of the Cult agenda and central parts of the Woke agenda and Woke was created and continues to be funded to an immense degree by Cult billionaires and corporations. If anyone begins to say 'coincidence' the syllables should stick in their throat.

Billionaire 'social justice warriors'

Joe Biden is a 100 percent-owned asset of the Cult and the Wokers' man in the White House whenever he can remember his name and for however long he lasts with his rapidly diminishing cognitive function. Even walking up the steps of an aircraft without falling on his arse would appear to be a challenge. He's not an empty-shell puppet or anything. From the minute Biden took office (or the Cult did) he began his executive orders promoting the Woke wish-list. You will see the Woke agenda imposed ever more severely because it's really the *Cult* agenda. Woke organisations and activist networks spawned by the Cult are funded to the extreme so long as they promote what the Cult wants to happen. Woke is funded to promote 'social justice' by billionaires who become billionaires by destroying social justice. The social justice mantra is only a cover for dismantling social justice and funded by billionaires that couldn't give a damn about social justice. Everything makes sense when you see that. One of Woke's premier funders is Cult billionaire financier George Soros who said: 'I am basically there to make money, I cannot and do not look at the social consequences of what I do.' This is the same Soros who has given more than $32 billion to his Open Society Foundations global Woke network and funded Black Lives Matter, mass immigration into Europe and the United States, transgender activism, climate change activism, political correctness and groups targeting 'white supremacy' in the form of privileged white thugs that dominate Antifa. What a scam it all is and when

you are dealing with the unquestioning fact-free zone of Woke scamming them is child's play. All you need to pull it off in all these organisations are a few in-the-know agents of the Cult and an army of naïve, reframed, uninformed, narcissistic, know-nothings convinced of their own self-righteousness, self-purity and virtue.

Soros and fellow billionaires and billionaire corporations have poured hundreds of millions into Black Lives Matter and connected groups and promoted them to a global audience. None of this is motivated by caring about black people. These are the billionaires that have controlled and exploited a system that leaves millions of black people in abject poverty and deprivation which they do absolutely nothing to address. The same Cult networks funding BLM were behind the *slave trade!* Black Lives Matter hijacked a phrase that few would challenge and they have turned this laudable concept into a political weapon to divide society. You know that BLM is a fraud when it claims that *All* Lives Matter, the most inclusive statement of all, is 'racist'. BLM and its Cult masters don't want to end racism. To them it's a means to an end to control all of humanity never mind the colour, creed, culture or background. What has destroying the nuclear family got to do with ending racism? Nothing – but that is one of the goals of BLM and also happens to be a goal of the Cult as I have been exposing in my books for decades. Stealing children from loving parents and giving schools ever more power to override parents is part of that same agenda. BLM is a Marxist organisation and why would that not be the case when the Cult created Marxism *and* BLM? Patrisse Cullors, a BLM co-founder, said in a 2015 video that she and her fellow organisers, including co-founder Alicia Garza, are 'trained Marxists'. The lady known after marriage as Patrisse Khan-Cullors bought a $1.4 million home in 2021 in one of the whitest areas of California with a black population of just 1.6 per cent and has so far bought *four* high-end homes for a total of $3.2 million. How very Marxist. There must be a bit of spare in the BLM coffers, however, when Cult corporations and billionaires have handed over the best part of $100 million. Many black people can see that Black Lives Matter is not

working for them, but against them, and this is still more confirmation. Black journalist Jason Whitlock, who had his account suspended by Twitter for simply linking to the story about the 'Marxist's' home buying spree, said that BLM leaders are 'making millions of dollars off the backs of these dead black men who they wouldn't spit on if they were on fire and alive'.

Black Lies Matter

Cult assets and agencies came together to promote BLM in the wake of the death of career criminal George Floyd who had been jailed a number of times including for forcing his way into the home of a black woman with others in a raid in which a gun was pointed at her stomach. Floyd was filmed being held in a Minneapolis street in 2020 with the knee of a police officer on his neck and he subsequently died. It was an appalling thing for the officer to do, but the same technique has been used by police on peaceful protestors of lockdown without any outcry from the Woke brigade. As unquestioning supporters of the Cult agenda Wokers have supported lockdown and all the 'Covid' claptrap while attacking anyone standing up to the tyranny imposed in its name. Court documents would later include details of an autopsy on Floyd by County Medical Examiner Dr Andrew Baker who concluded that Floyd had taken a fatal level of the drug fentanyl. None of this mattered to fact-free, question-free, Woke. Floyd's death was followed by worldwide protests against police brutality amid calls to defund the police. Throwing babies out with the bathwater is a Woke speciality. In the wake of the murder of British woman Sarah Everard a Green Party member of the House of Lords, Baroness Jones of Moulescoomb (Nincompoopia would have been better), called for a 6pm curfew for all men. This would be in breach of the Geneva Conventions on war crimes which ban collective punishment, but that would never have crossed the black and white Woke mind of Baroness Nincompoopia who would have been far too convinced of her own self-righteousness to compute such details. Many American cities did defund the police in the face of Floyd riots

and after $15 million was deleted from the police budget in Washington DC under useless Woke mayor Muriel Bowser car-jacking alone rose by 300 percent and within six months the US capital recorded its highest murder rate in 15 years. The same happened in Chicago and other cities in line with the Cult/Soros plan to bring fear to streets and neighbourhoods by reducing the police, releasing violent criminals and not prosecuting crime. This is the mob-rule agenda that I have warned in the books was coming for so long. Shootings in the area of Minneapolis where Floyd was arrested increased by 2,500 percent compared with the year before. Defunding the police over George Floyd has led to a big increase in dead people with many of them black. Police protection for politicians making these decisions stayed the same or increased as you would expect from professional hypocrites. The Cult doesn't actually want to abolish the police. It wants to abolish local control over the police and hand it to federal government as the psychopaths advance the Hunger Games Society. Many George Floyd protests turned into violent riots with black stores and businesses destroyed by fire and looting across America fuelled by Black Lives Matter. Woke doesn't do irony. If you want civil rights you must loot the liquor store and the supermarket and make off with a smart TV. It's the only way.

It's not a race war – it's a class war

Black people are patronised by privileged blacks and whites alike and told they are victims of white supremacy. I find it extraordinary to watch privileged blacks supporting the very system and bloodline networks behind the slave trade and parroting the same Cult-serving manipulative crap of their privileged white, often billionaire, associates. It is indeed not a race war but a class war and colour is just a diversion. Black Senator Cory Booker and black Congresswoman Maxine Waters, more residents of Nincompoopia, personify this. Once you tell people they are victims of someone else you devalue both their own responsibility for their plight and the power they have to impact on their reality and experience. Instead

we have: 'You are only in your situation because of whitey – turn on them and everything will change.' It won't change. Nothing changes in our lives unless *we* change it. Crucial to that is never seeing yourself as a victim and always as the creator of your reality. Life is a simple sequence of choice and consequence. Make different choices and you create different consequences. *You* have to make those choices – not Black Lives Matter, the Woke Mafia and anyone else that seeks to dictate your life. Who are they these Wokers, an emotional and psychological road traffic accident, to tell you what to do? Personal empowerment is the last thing the Cult and its Black Lives Matter want black people or anyone else to have. They claim to be defending the underdog while *creating* and perpetuating the underdog. The Cult's worst nightmare is human unity and if they are going to keep blacks, whites and every other race under economic servitude and control then the focus must be diverted from what they have in common to what they can be manipulated to believe divides them. Blacks have to be told that their poverty and plight is the fault of the white bloke living on the street in the same poverty and with the same plight they are experiencing. The difference is that your plight black people is due to him, a white supremacist with 'white privilege' living on the street. Don't unite as one human family against your mutual oppressors and suppressors – fight the oppressor with the white face who is as financially deprived as you are. The Cult knows that as its 'Covid' agenda moves into still new levels of extremism people are going to respond and it has been spreading the seeds of disunity everywhere to stop a united response to the evil that targets *all of us*.

Racist attacks on 'whiteness' are getting ever more outrageous and especially through the American Democratic Party which has an appalling history for anti-black racism. Barack Obama, Joe Biden, Hillary Clinton and Nancy Pelosi all eulogised about Senator Robert Byrd at his funeral in 2010 after a nearly 60-year career in Congress. Byrd was a brutal Ku Klux Klan racist and a violent abuser of Cathy O'Brien in MKUltra. He said he would never fight in the military 'with a negro by my side' and 'rather I should die a thousand times,

and see Old Glory trampled in the dirt never to rise again, than to see this beloved land of ours become degraded by race mongrels, a throwback to the blackest specimen from the wilds'. Biden called Byrd a 'very close friend and mentor'. These 'Woke' hypocrites are not anti-racist they are anti-poor and anti-people not of their perceived class. Here is an illustration of the scale of anti-white racism to which we have now descended. Seriously Woke and moronic *New York Times* contributor Damon Young described whiteness as a 'virus' that 'like other viruses will not die until there are no bodies left for it to infect'. He went on: '… the only way to stop it is to locate it, isolate it, extract it, and kill it.' Young can say that as a black man with no consequences when a white man saying the same in reverse would be facing a jail sentence. *That's* racism. We had super-Woke numbskull senators Tammy Duckworth and Mazie Hirono saying they would object to future Biden Cabinet appointments if he did not nominate more Asian Americans and Pacific Islanders. Never mind the ability of the candidate what do they look like? Duckworth said: 'I will vote for racial minorities and I will vote for LGBTQ, but anyone else I'm not voting for.' Appointing people on the grounds of race is illegal, but that was not a problem for this ludicrous pair. They were on-message and that's a free pass in any situation.

Critical race racism

White children are told at school they are intrinsically racist as they are taught the divisive 'critical race theory'. This claims that the law and legal institutions are inherently racist and that race is a socially constructed concept used by white people to further their economic and political interests at the expense of people of colour. White is a 'virus' as we've seen. Racial inequality results from 'social, economic, and legal differences that white people create between races to maintain white interests which leads to poverty and criminality in minority communities'. I must tell that to the white guy sleeping on the street. The principal of East Side Community School in New York sent white parents a manifesto that called on

them to become 'white traitors' and advocate for full 'white abolition'. These people are teaching your kids when they urgently need a psychiatrist. The 'school' included a chart with 'eight white identities' that ranged from 'white supremacist' to 'white abolition' and defined the behaviour white people must follow to end 'the regime of whiteness'. Woke blacks and their privileged white associates are acting exactly like the slave owners of old and Ku Klux Klan racists like Robert Byrd. They are too full of their own self-purity to see that, but it's true. Racism is not a body type; it's a state of mind that can manifest through any colour, creed or culture.

Another racial fraud is *'equity'*. Not equality of treatment and opportunity – equity. It's a term spun as equality when it means something very different. Equality in its true sense is a raising up while 'equity' is a race to the bottom. Everyone in the same level of poverty is 'equity'. Keep everyone down – that's equity. The Cult doesn't want anyone in the human family to be empowered and BLM leaders, like all these 'anti-racist' organisations, continue their privileged, pampered existence by perpetuating the perception of gathering racism. When is the last time you heard an 'anti-racist' or 'anti-Semitism' organisation say that acts of racism and discrimination have *fallen?* It's not in the interests of their fund-raising and power to influence and the same goes for the professional soccer anti-racism operation, Kick It Out. Two things confirmed that the Black Lives Matter riots in the summer of 2020 were Cult creations. One was that while anti-lockdown protests were condemned in this same period for 'transmitting 'Covid' the authorities supported mass gatherings of Black Lives Matter supporters. I even saw self-deluding people claiming to be doctors say the two types of protest were not the same. No – the non-existent 'Covid' was in favour of lockdowns and attacked those that protested against them while 'Covid' supported Black Lives Matter and kept well away from its protests. The whole thing was a joke and as lockdown protestors were arrested, often brutally, by reframed Face-Nappies we had the grotesque sight of police officers taking the knee to Black Lives Matter, a Cult-funded Marxist

organisation that supports violent riots and wants to destroy the nuclear family and white people.

He's not white? Shucks!

Woke obsession with race was on display again when ten people were shot dead in Boulder, Colorado, in March, 2021. Cult-owned Woke TV channels like CNN said the shooter appeared to be a white man and Wokers were on Twitter condemning 'violent white men' with the usual mantras. Then the shooter's name was released as Ahmad Al Aliwi Alissa, an anti-Trump Arab-American, and the sigh of disappointment could be heard five miles away. Never mind that ten people were dead and what that meant for their families. Race baiting was all that mattered to these sick Cult-serving people like Barack Obama who exploited the deaths to further divide America on racial grounds which is his job for the Cult. This is the man that 'racist' white Americans made the first black president of the United States and then gave him a second term. Not-very-bright Obama has become filthy rich on the back of that and today appears to have a big influence on the Biden administration. Even so he's still a downtrodden black man and a victim of white supremacy. This disingenuous fraud reveals the contempt he has for black people when he puts on a Deep South Alabama accent whenever he talks to them, no, *at* them.

Another BLM red flag was how the now fully-Woke (fully-Cult) and fully-virtue-signalled professional soccer authorities had their teams taking the knee before every match in support of Marxist Black Lives Matter. Soccer authorities and clubs displayed 'Black Lives Matter' on the players' shirts and flashed the name on electronic billboards around the pitch. Any fans that condemned what is a Freemasonic taking-the-knee ritual were widely condemned as you would expect from the Woke virtue-signallers of professional sport and the now fully-Woke media. We have reverse racism in which you are banned from criticising any race or culture except for white people for whom anything goes – say what you like, no problem. What has this got to do with racial harmony and

equality? We've had black supremacists from Black Lives Matter telling white people to fall to their knees in the street and apologise for their white supremacy. Black supremacists acting like white supremacist slave owners of the past couldn't breach their self-obsessed, race-obsessed sense of self-purity. Joe Biden appointed a race-obsessed black supremacist Kristen Clarke to head the Justice Department Civil Rights Division. Clarke claimed that blacks are endowed with 'greater mental, physical and spiritual abilities' than whites. If anyone reversed that statement they would be vilified. Clarke is on-message so no problem. She's never seen a black-white situation in which the black figure is anything but a virtuous victim and she heads the Civil Rights Division which should treat everyone the same or it isn't civil rights. Another perception of the Renegade Mind: If something or someone is part of the Cult agenda they will be supported by Woke governments and media no matter what. If they're not, they will be condemned and censored. It really is that simple and so racist Clarke prospers despite (make that because of) her racism.

The end of culture

Biden's administration is full of such racial, cultural and economic bias as the Cult requires the human family to be divided into warring factions. We are now seeing racially-segregated graduations and everything, but everything, is defined through the lens of perceived 'racism. We have 'racist' mathematics, 'racist' food and even 'racist' *plants*. World famous Kew Gardens in London said it was changing labels on plants and flowers to tell its pre-'Covid' more than two million visitors a year how racist they are. Kew director Richard Deverell said this was part of an effort to 'move quickly to decolonise collections' after they were approached by one Ajay Chhabra 'an actor with an insight into how sugar cane was linked to slavery'. They are *plants* you idiots. 'Decolonisation' in the Woke manual really means colonisation of society with its mentality and by extension colonisation by the Cult. We are witnessing a new Chinese-style 'Cultural Revolution' so essential to the success of all

Marxist takeovers. Our cultural past and traditions have to be swept away to allow a new culture to be built-back-better. Woke targeting of long-standing Western cultural pillars including historical monuments and cancelling of historical figures is what happened in the Mao revolution in China which 'purged remnants of capitalist and traditional elements from Chinese society' and installed Maoism as the dominant ideology'. For China see the Western world today and for 'dominant ideology' see Woke. Better still see Marxism or Maoism. The 'Covid' hoax has specifically sought to destroy the arts and all elements of Western culture from people meeting in a pub or restaurant to closing theatres, music venues, sports stadiums, places of worship and even banning *singing*. Destruction of Western society is also why criticism of any religion is banned except for Christianity which again is the dominant religion as white is the numerically-dominant race. Christianity may be fading rapidly, but its history and traditions are weaved through the fabric of Western society. Delete the pillars and other structures will follow until the whole thing collapses. I am not a Christian defending that religion when I say that. I have no religion. It's just a fact. To this end Christianity has itself been turned Woke to usher its own downfall and its ranks are awash with 'change agents' – knowing and unknowing – at every level including Pope Francis (*definitely* knowing) and the clueless Archbishop of Canterbury Justin Welby (possibly not, but who can be sure?). Woke seeks to coordinate attacks on Western culture, traditions, and ways of life through 'intersectionality' defined as 'the complex, cumulative way in which the effects of multiple forms of discrimination (such as racism, sexism, and classism) combine, overlap, or intersect especially in the experiences of marginalised individuals or groups'. Wade through the Orwellian Woke-speak and this means coordinating disparate groups in a common cause to overthrow freedom and liberal values.

The entire structure of public institutions has been infested with Woke – government at all levels, political parties, police, military, schools, universities, advertising, media and trade unions. This abomination has been achieved through the Cult web by appointing

Wokers to positions of power and battering non-Wokers into line through intimidation, isolation and threats to their job. Many have been fired in the wake of the empathy-deleted, vicious hostility of 'social justice' Wokers and the desire of gutless, spineless employers to virtue-signal their Wokeness. Corporations are filled with Wokers today, most notably those in Silicon Valley. Ironically at the top they are not Woke at all. They are only exploiting the mentality their Cult masters have created and funded to censor and enslave while the Wokers cheer them on until it's their turn. Thus the Woke 'liberal left' is an inversion of the traditional liberal left. Campaigning for justice on the grounds of power and wealth distribution has been replaced by campaigning for identity politics. The genuine traditional left would never have taken money from today's billionaire abusers of fairness and justice and nor would the billionaires have wanted to fund that genuine left. It would not have been in their interests to do so. The division of opinion in those days was between the haves and have nots. This all changed with Cult manipulated and funded identity politics. The division of opinion today is between Wokers and non-Wokers and not income brackets. Cult corporations and their billionaires may have taken wealth disparity to cataclysmic levels of injustice, but as long as they speak the language of Woke, hand out the dosh to the Woke network and censor the enemy they are 'one of us'. Billionaires who don't give a damn about injustice are laughing at them till their bellies hurt. Wokers are not even close to self-aware enough to see that. The transformed 'left' dynamic means that Wokers who drone on about 'social justice' are funded by billionaires that have destroyed social justice the world over. It's *why* they are billionaires.

The climate con

Nothing encapsulates what I have said more comprehensively than the hoax of human-caused global warming. I have detailed in my books over the years how Cult operatives and organisations were the pump-primers from the start of the climate con. A purpose-built vehicle for this is the Club of Rome established by the Cult in 1968

with the Rockefellers and Rothschilds centrally involved all along. Their gofer frontman Maurice Strong, a Canadian oil millionaire, hosted the Earth Summit in Rio de Janeiro, Brazil, in 1992 where the global 'green movement' really expanded in earnest under the guiding hand of the Cult. The Earth Summit established Agenda 21 through the Cult-created-and-owned United Nations to use the illusion of human-caused climate change to justify the transformation of global society to save the world from climate disaster. It is a No-Problem-Reaction-Solution sold through governments, media, schools and universities as whole generations have been terrified into believing that the world was going to end in their lifetimes unless what old people had inflicted upon them was stopped by a complete restructuring of how everything is done. Chill, kids, it's all a hoax. Such restructuring is precisely what the Cult agenda demands (purely by coincidence of course). Today this has been given the codename of the Great Reset which is only an updated term for Agenda 21 and its associated Agenda 2030. The latter, too, is administered through the UN and was voted into being by the General Assembly in 2015. Both 21 and 2030 seek centralised control of all resources and food right down to the raindrops falling on your own land. These are some of the demands of Agenda 21 established in 1992. See if you recognise this society emerging today:

- End national sovereignty
- State planning and management of all land resources, ecosystems, deserts, forests, mountains, oceans and fresh water; agriculture; rural development; biotechnology; and ensuring *'equity'*
- The state to 'define the role' of business and financial resources
- Abolition of private property
- 'Restructuring' the family unit (see BLM)
- Children raised by the state
- People told what their job will be
- Major restrictions on movement
- Creation of 'human settlement zones'

- Mass resettlement as people are forced to vacate land where they live
- Dumbing down education
- Mass global depopulation in pursuit of all the above

The United Nations was created as a Trojan horse for world government. With the climate con of critical importance to promoting that outcome you would expect the UN to be involved. Oh, it's involved all right. The UN is promoting Agenda 21 and Agenda 2030 justified by 'climate change' while also driving the climate hoax through its Intergovernmental Panel on Climate Change (IPCC), one of the world's most corrupt organisations. The IPCC has been lying ferociously and constantly since the day it opened its doors with the global media hanging unquestioningly on its every mendacious word. The Green movement is entirely Woke and has long lost its original environmental focus since it was co-opted by the Cult. An obsession with 'global warming' has deleted its values and scrambled its head. I experienced a small example of what I mean on a beautiful country walk that I have enjoyed several times a week for many years. The path merged into the fields and forests and you felt at one with the natural world. Then a 'Green' organisation, the Hampshire and Isle of Wight Wildlife Trust, took over part of the land and proceeded to cut down a large number of trees, including mature ones, to install a horrible big, bright steel 'this-is-ours-stay-out' fence that destroyed the whole atmosphere of this beautiful place. No one with a feel for nature would do that. Day after day I walked to the sound of chainsaws and a magnificent mature weeping willow tree that I so admired was cut down at the base of the trunk. When I challenged a Woke young girl in a green shirt (of course) about this vandalism she replied: 'It's a weeping willow – it will grow back.' This is what people are paying for when they donate to the Hampshire and Isle of Wight Wildlife Trust and many other 'green' organisations today. It is not the environmental movement that I knew and instead has become a support-system – as with Extinction Rebellion – for a very dark agenda.

Private jets for climate justice

The Cult-owned, Gates-funded, World Economic Forum and its founder Klaus Schwab were behind the emergence of Greta Thunberg to harness the young behind the climate agenda and she was invited to speak to the world at … the UN. Schwab published a book, *Covid-19: The Great Reset* in 2020 in which he used the 'Covid' hoax and the climate hoax to lay out a new society straight out of Agenda 21 and Agenda 2030. Bill Gates followed in early 2021 when he took time out from destroying the world to produce a book in his name about the way to save it. Gates flies across the world in private jets and admitted that 'I probably have one of the highest greenhouse gas footprints of anyone on the planet … my personal flying alone is gigantic.' He has also bid for the planet's biggest private jet operator. Other climate change saviours who fly in private jets include John Kerry, the US Special Presidential Envoy for Climate, and actor Leonardo DiCaprio, a 'UN Messenger of Peace with special focus on climate change'. These people are so full of bullshit they could corner the market in manure. We mustn't be sceptical, though, because the Gates book, *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need*, is a genuine attempt to protect the world and not an obvious pile of excrement attributed to a mega-psychopath aimed at selling his masters' plans for humanity. The Gates book and the other shite-pile by Klaus Schwab could have been written by the same person and may well have been. Both use 'climate change' and 'Covid' as the excuses for their new society and by coincidence the Cult's World Economic Forum and Bill and Melinda Gates Foundation promote the climate hoax and hosted Event 201 which pre-empted with a 'simulation' the very 'coronavirus' hoax that would be simulated for real on humanity within weeks. The British 'royal' family is promoting the 'Reset' as you would expect through Prince 'climate change caused the war in Syria' Charles and his hapless son Prince William who said that we must 'reset our relationship with nature and our trajectory as a species' to avoid a climate disaster. Amazing how many promotors of the 'Covid' and 'climate change' control

systems are connected to Gates and the World Economic Forum. A 'study' in early 2021 claimed that carbon dioxide emissions must fall by the equivalent of a global lockdown roughly every two years for the next decade to save the planet. The 'study' appeared in the same period that the Schwab mob claimed in a video that lockdowns destroying the lives of billions are good because they make the earth 'quieter' with less 'ambient noise'. They took down the video amid a public backlash for such arrogant, empathy-deleted stupidity You see, however, where they are going with this. Corinne Le Quéré, a professor at the Tyndall Centre for Climate Change Research, University of East Anglia, was lead author of the climate lockdown study, and she writes for … the World Economic Forum. Gates calls in 'his' book for changing 'every aspect of the economy' (long-time Cult agenda) and for humans to eat synthetic 'meat' (predicted in my books) while cows and other farm animals are eliminated. Australian TV host and commentator Alan Jones described what carbon emission targets would mean for farm animals in Australia alone if emissions were reduced as demanded by 35 percent by 2030 and zero by 2050:

Well, let's take agriculture, the total emissions from agriculture are about 75 million tonnes of carbon dioxide, equivalent. Now reduce that by 35 percent and you have to come down to 50 million tonnes, I've done the maths. So if you take for example 1.5 million cows, you're going to have to reduce the herd by 525,000 [by] 2030, nine years, that's 58,000 cows a year. The beef herd's 30 million, reduce that by 35 percent, that's 10.5 million, which means 1.2 million cattle have to go every year between now and 2030. This is insanity!

There are 75 million sheep. Reduce that by 35 percent, that's 26 million sheep, that's almost 3 million a year. So under the Paris Agreement over 30 million beasts. dairy cows, cattle, pigs and sheep would go. More than 8,000 every minute of every hour for the next decade, do these people know what they're talking about?

Clearly they don't at the level of campaigners, politicians and administrators. The Cult *does* know; that's the outcome it wants. We are faced with not just a war on humanity. Animals and the natural world are being targeted and I have been saying since the 'Covid' hoax began that the plan eventually was to claim that the 'deadly virus' is able to jump from animals, including farm animals and

domestic pets, to humans. Just before this book went into production came this story: 'Russia registers world's first Covid-19 vaccine for cats & dogs as makers of Sputnik V warn pets & farm animals could spread virus'. The report said 'top scientists warned that the deadly pathogen could soon begin spreading through homes and farms' and 'the next stage is the infection of farm and domestic animals'. Know the outcome and you'll see the journey. Think what that would mean for animals and keep your eye on a term called zoonosis or zoonotic diseases which transmit between animals and humans. The Cult wants to break the connection between animals and people as it does between people and people. Farm animals fit with the Cult agenda to transform food from natural to synthetic.

The gas of life is killing us

There can be few greater examples of Cult inversion than the condemnation of carbon dioxide as a dangerous pollutant when it is the gas of life. Without it the natural world would be dead and so we would all be dead. We breathe in oxygen and breathe out carbon dioxide while plants produce oxygen and absorb carbon dioxide. It is a perfect symbiotic relationship that the Cult wants to dismantle for reasons I will come to in the final two chapters. Gates, Schwab, other Cult operatives and mindless repeaters, want the world to be 'carbon neutral' by at least 2050 and the earlier the better. 'Zero carbon' is the cry echoed by lunatics calling for 'Zero Covid' when we already have it. These carbon emission targets will deindustrialise the world in accordance with Cult plans – the post-industrial, post-democratic society – and with so-called renewables like solar and wind not coming even close to meeting human energy needs blackouts and cold are inevitable. Texans got the picture in the winter of 2021 when a snow storm stopped wind turbines and solar panels from working and the lights went down along with water which relies on electricity for its supply system. Gates wants everything to be powered by electricity to ensure that his masters have the kill switch to stop all human activity, movement, cooking, water and warmth any time they like. The climate lie is so

stupendously inverted that it claims we must urgently reduce carbon dioxide when we *don't have enough*.

Co2 in the atmosphere is a little above 400 parts per million when the optimum for plant growth is 2,000 ppm and when it falls anywhere near 150 ppm the natural world starts to die and so do we. It fell to as low as 280 ppm in an 1880 measurement in Hawaii and rose to 413 ppm in 2019 with industrialisation which is why the planet has become *greener* in the industrial period. How insane then that psychopathic madman Gates is not satisfied only with blocking the rise of Co2. He's funding technology to suck it out of the atmosphere. The reason why will become clear. The industrial era is not destroying the world through Co2 and has instead turned around a potentially disastrous ongoing fall in Co2. Greenpeace co-founder and scientist Patrick Moore walked away from Greenpeace in 1986 and has exposed the green movement for fear-mongering and lies. He said that 500 million years ago there was *17 times* more Co2 in the atmosphere than we have today and levels have been falling for hundreds of millions of years. In the last 150 million years Co2 levels in Earth's atmosphere had reduced by *90 percent*. Moore said that by the time humanity began to unlock carbon dioxide from fossil fuels we were at '38 seconds to midnight' and in that sense: 'Humans are [the Earth's] salvation.' Moore made the point that only half the Co2 emitted by fossil fuels stays in the atmosphere and we should remember that all pollution pouring from chimneys that we are told is carbon dioxide is in fact nothing of the kind. It's pollution. Carbon dioxide is an invisible gas.

William Happer, Professor of Physics at Princeton University and long-time government adviser on climate, has emphasised the Co2 deficiency for maximum growth and food production. Greenhouse growers don't add carbon dioxide for a bit of fun. He said that most of the warming in the last 100 years, after the earth emerged from the super-cold period of the 'Little Ice Age' into a natural warming cycle, was over by 1940. Happer said that a peak year for warming in 1988 can be explained by a 'monster El Nino' which is a natural and cyclical warming of the Pacific that has nothing to do with 'climate

change'. He said the effect of Co2 could be compared to painting a wall with red paint in that once two or three coats have been applied it didn't matter how much more you slapped on because the wall will not get much redder. Almost all the effect of the rise in Co2 has already happened, he said, and the volume in the atmosphere would now have to *double* to increase temperature by a single degree. Climate hoaxers know this and they have invented the most ridiculously complicated series of 'feedback' loops to try to overcome this rather devastating fact. You hear puppet Greta going on cluelessly about feedback loops and this is why.

The Sun affects temperature? No you *climate denier*

Some other nonsense to contemplate: Climate graphs show that rises in temperature do not follow rises in Co2 – *it's the other way round* with a lag between the two of some 800 years. If we go back 800 years from present time we hit the Medieval Warm Period when temperatures were higher than now without any industrialisation and this was followed by the Little Ice Age when temperatures plummeted. The world was still emerging from these centuries of serious cold when many climate records began which makes the ever-repeated line of the 'hottest year since records began' meaningless when you are not comparing like with like. The coldest period of the Little Ice Age corresponded with the lowest period of sunspot activity when the Sun was at its least active. Proper scientists will not be at all surprised by this when it confirms the obvious fact that earth temperature is affected by the scale of Sun activity and the energetic power that it subsequently emits; but when is the last time you heard a climate hoaxer talking about the Sun as a source of earth temperature?? Everything has to be focussed on Co2 which makes up just 0.117 percent of so-called greenhouse gases and only a fraction of even that is generated by human activity. The rest is natural. More than *90 percent* of those greenhouse gases are water vapour and clouds (Fig 9). Ban moisture I say. Have you noticed that the climate hoaxers no longer use the polar bear as their promotion image? That's because far from becoming extinct polar

bear communities are stable or thriving. Joe Bastardi, American meteorologist, weather forecaster and outspoken critic of the climate lie, documents in his book *The Climate Chronicles* how weather patterns and events claimed to be evidence of climate change have been happening since long before industrialisation: 'What happened before naturally is happening again, as is to be expected given the cyclical nature of the climate due to the design of the planet.' If you read the detailed background to the climate hoax in my other books you will shake your head and wonder how anyone could believe the crap which has spawned a multi-trillion dollar industry based on absolute garbage (see HIV causes AIDs and Sars-Cov-2 causes 'Covid-19'). Climate and 'Covid' have much in common given they have the same source. They both have the contradictory *everything* factor in which everything is explained by reference to them. It's hot – 'it's climate change'. It's cold – 'it's climate change'. I got a sniffle – 'it's Covid'. I haven't got a sniffle – 'it's Covid'. Not having a sniffle has to be a symptom of 'Covid'. Everything is and not having a sniffle is especially dangerous if you are a slow walker. For sheer audacity I offer you a Cambridge University 'study' that actually linked 'Covid' to 'climate change'. It had to happen eventually. They concluded that climate change played a role in 'Covid-19' spreading from animals to humans because … wait for it … I kid you not … *the two groups were forced closer together as populations grow*. Er, that's it. The whole foundation on which this depended was that 'Bats are the likely zoonotic origin of SARS-CoV-1 and SARS-CoV-2'. Well, they are not. They are nothing to do with it. Apart from bats not being the origin and therefore 'climate change' effects on bats being irrelevant I am in awe of their academic insight. Where would we be without them? Not where we are that's for sure.

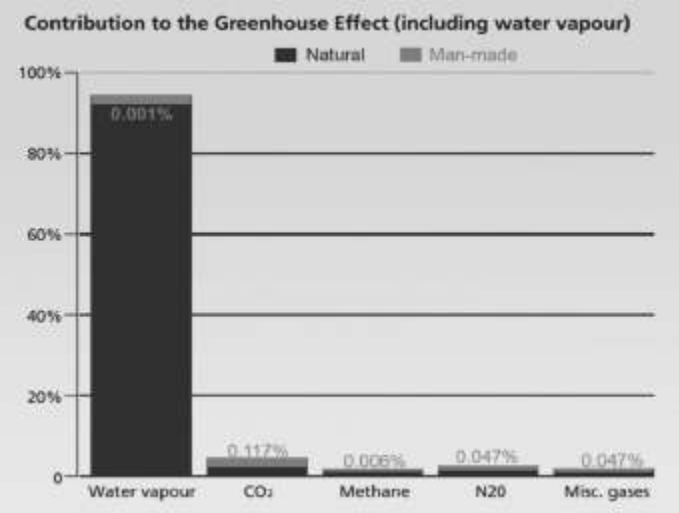


Figure 9: The idea that the gas of life is disastrously changing the climate is an insult to brain cell activity.

One other point about the weather is that climate modification is now well advanced and not every major weather event is natural – or earthquake come to that. I cover this subject at some length in other books. China is openly planning a rapid expansion of its weather modification programme which includes changing the climate in an area more than one and a half times the size of India. China used weather manipulation to ensure clear skies during the 2008 Olympics in Beijing. I have quoted from US military documents detailing how to employ weather manipulation as a weapon of war and they did that in the 1960s and 70s during the conflict in Vietnam with Operation Popeye manipulating monsoon rains for military purposes. Why would there be international treaties on weather modification if it wasn't possible? Of course it is. Weather is energetic information and it can be changed.

How was the climate hoax pulled off? See 'Covid'

If you can get billions to believe in a 'virus' that doesn't exist you can get them to believe in human-caused climate change that doesn't exist. Both are being used by the Cult to transform global society in the way it has long planned. Both hoaxes have been achieved in pretty much the same way. First you declare a lie is a fact. There's a

'virus' you call SARS-Cov-2 or humans are warming the planet with their behaviour. Next this becomes, via Cult networks, the foundation of government, academic and science policy and belief. Those who parrot the mantra are given big grants to produce research that confirms the narrative is true and ever more 'symptoms' are added to make the 'virus'/'climate change' sound even more scary. Scientists and researchers who challenge the narrative have their grants withdrawn and their careers destroyed. The media promote the lie as the unquestionable truth and censor those with an alternative view or evidence. A great percentage of the population believe what they are told as the lie becomes an everybody-knows-that and the believing-masses turn on those with a mind of their own. The technique has been used endlessly throughout human history. Wokers are the biggest promotors of the climate lie *and* 'Covid' fascism because their minds are owned by the Cult; their sense of self-righteous self-purity knows no bounds; and they exist in a bubble of reality in which facts are irrelevant and only get in the way of looking without seeing.

Running through all of this like veins in a blue cheese is control of information, which means control of perception, which means control of behaviour, which collectively means control of human society. The Cult owns the global media and Silicon Valley fascists for the simple reason that it *has* to. Without control of information it can't control perception and through that human society. Examine every facet of the Cult agenda and you will see that anything supporting its introduction is never censored while anything pushing back is always censored. I say again: Psychopaths that know why they are doing this must go before Nuremberg trials and those that follow their orders must trot along behind them into the same dock. 'I was just following orders' didn't work the first time and it must not work now. Nuremberg trials must be held all over the world before public juries for politicians, government officials, police, compliant doctors, scientists and virologists, and all Cult operatives such as Gates, Tedros, Fauci, Vallance, Whitty, Ferguson, Zuckerberg, Wojcicki, Brin, Page, Dorsey, the whole damn lot of

them – including, no *especially*, the psychopath psychologists. Without them and the brainless, gutless excuses for journalists that have repeated their lies, none of this could be happening. Nobody can be allowed to escape justice for the psychological and economic Armageddon they are all responsible for visiting upon the human race.

As for the compliant, unquestioning, swathes of humanity, and the self-obsessed, all-knowing ignorance of the Wokers … don't start me. God help their kids. God help their grandkids. God *help them*.

CHAPTER NINE

We must have it? So what is it?

Well I won't back down. No, I won't back down. You can stand me up at the Gates of Hell. But I won't back down
Tom Petty

I will now focus on the genetically-manipulating 'Covid vaccines' which do not meet this official definition of a vaccine by the US Centers for Disease Control (CDC): 'A product that stimulates a person's immune system to produce immunity to a specific disease, protecting the person from that disease.' On that basis 'Covid vaccines' are not a vaccine in that the makers don't even claim they stop infection or transmission.

They are instead part of a multi-levelled conspiracy to change the nature of the human body and what it means to be 'human' and to depopulate an enormous swathe of humanity. What I shall call Human 1.0 is on the cusp of becoming Human 2.0 and for very sinister reasons. Before I get to the 'Covid vaccine' in detail here's some background to vaccines in general. Government regulators do not test vaccines – the makers do – and the makers control which data is revealed and which isn't. Children in America are given 50 vaccine doses by age six and 69 by age 19 and the effect of the whole combined schedule has never been tested. Autoimmune diseases when the immune system attacks its own body have soared in the mass vaccine era and so has disease in general in children and the young. Why wouldn't this be the case when vaccines target the *immune system?* The US government gave Big Pharma drug

companies immunity from prosecution for vaccine death and injury in the 1986 National Childhood Vaccine Injury Act (NCVIA) and since then the government (taxpayer) has been funding compensation for the consequences of Big Pharma vaccines. The criminal and satanic drug giants can't lose and the vaccine schedule has increased dramatically since 1986 for this reason. There is no incentive to make vaccines safe and a big incentive to make money by introducing ever more. Even against a ridiculously high bar to prove vaccine liability, and with the government controlling the hearing in which it is being challenged for compensation, the vaccine court has so far paid out more than $4 billion. These are the vaccines we are told are safe and psychopaths like Zuckerberg censor posts saying otherwise. The immunity law was even justified by a ruling that vaccines by their nature were 'unavoidably unsafe'.

Check out the ingredients of vaccines and you will be shocked if you are new to this. *They put that in children's bodies?? What??* Try aluminium, a brain toxin connected to dementia, aborted foetal tissue and formaldehyde which is used to embalm corpses. World-renowned aluminium expert Christopher Exley had his research into the health effect of aluminium in vaccines shut down by Keele University in the UK when it began taking funding from the Bill and Melinda Gates Foundation. Research when diseases 'eradicated' by vaccines began to decline and you will find the fall began long *before* the vaccine was introduced. Sometimes the fall even plateaued after the vaccine. Diseases like scarlet fever for which there was no vaccine declined in the same way because of environmental and other factors. A perfect case in point is the polio vaccine. Polio began when lead arsenate was first sprayed as an insecticide and residues remained in food products. Spraying started in 1892 and the first US polio epidemic came in Vermont in 1894. The simple answer was to stop spraying, but Rockefeller-created Big Pharma had a better idea. Polio was decreed to be caused by the *poliovirus* which 'spreads from person to person and can infect a person's spinal cord'. Lead arsenate was replaced by the lethal DDT which had the same effect of causing paralysis by damaging the brain and central nervous

system. Polio plummeted when DDT was reduced and then banned, but the vaccine is still given the credit for something it didn't do. Today by far the biggest cause of polio is the vaccines promoted by Bill Gates. Vaccine justice campaigner Robert Kennedy Jr, son of assassinated (by the Cult) US Attorney General Robert Kennedy, wrote:

> In 2017, the World Health Organization (WHO) reluctantly admitted that the global explosion in polio is predominantly vaccine strain. The most frightening epidemics in Congo, Afghanistan, and the Philippines, are all linked to vaccines. In fact, by 2018, 70% of global polio cases were vaccine strain.

Vaccines make fortunes for Cult-owned Gates and Big Pharma while undermining the health and immune systems of the population. We had a glimpse of the mentality behind the Big Pharma cartel with a report on WION (World is One News), an international English language TV station based in India, which exposed the extraordinary behaviour of US drug company Pfizer over its 'Covid vaccine'. The WION report told how Pfizer had made fantastic demands of Argentina, Brazil and other countries in return for its 'vaccine'. These included immunity from prosecution, even for Pfizer negligence, government insurance to protect Pfizer from law suits and handing over as collateral sovereign assets of the country to include Argentina's bank reserves, military bases and embassy buildings. Pfizer demanded the same of Brazil in the form of waiving sovereignty of its assets abroad; exempting Pfizer from Brazilian laws; and giving Pfizer immunity from all civil liability. This is a 'vaccine' developed with government funding. Big Pharma is evil incarnate as a creation of the Cult and all must be handed tickets to Nuremberg.

Phantom 'vaccine' for a phantom 'disease'

I'll expose the 'Covid vaccine' fraud and then go on to the wider background of why the Cult has set out to 'vaccinate' every man, woman and child on the planet for an alleged 'new disease' with a survival rate of 99.77 percent (or more) even by the grotesquely-

manipulated figures of the World Health Organization and Johns Hopkins University. The 'infection' to 'death' ratio is 0.23 to 0.15 percent according to Stanford epidemiologist Dr John Ioannidis and while estimates vary the danger remains tiny. I say that if the truth be told the fake infection to fake death ratio is zero. Never mind all the evidence I have presented here and in *The Answer* that there is no 'virus' let us just focus for a moment on that death-rate figure of say 0.23 percent. The figure includes all those worldwide who have tested positive with a test not testing for the 'virus' and then died within 28 days or even longer of any other cause – *any other cause*. Now subtract all those illusory 'Covid' deaths on the global data sheets from the 0.23 percent. What do you think you would be left with? *Zero*. A vaccination has never been successfully developed for a so-called coronavirus. They have all failed at the animal testing stage when they caused hypersensitivity to what they were claiming to protect against and made the impact of a disease far worse. Cult-owned vaccine corporations got around that problem this time by bypassing animal trials, going straight to humans and making the length of the 'trials' before the public rollout as short as they could get away with. Normally it takes five to ten years or more to develop vaccines that still cause demonstrable harm to many people and that's without including the long-term effects that are never officially connected to the vaccination. 'Covid' non-vaccines have been officially produced and approved in a matter of months from a standing start and part of the reason is that (a) they were developed before the 'Covid' hoax began and (b) they are based on computer programs and not natural sources. Official non-trials were so short that government agencies gave *emergency*, not full, approval. 'Trials' were not even completed and full approval cannot be secured until they are. Public 'Covid vaccination' is actually a *continuation of the trial*. Drug company 'trials' are not scheduled to end until 2023 by which time a lot of people are going to be dead. Data on which government agencies gave this emergency approval was supplied by the Big Pharma corporations themselves in the form of Pfizer/BioNTech, AstraZeneca, Moderna, Johnson & Johnson, and

others, and this is the case with all vaccines. By its very nature *emergency* approval means drug companies do not have to prove that the 'vaccine' is 'safe and effective'. How could they with trials way short of complete? Government regulators only have to *believe* that they *could* be safe and effective. It is criminal manipulation to get products in circulation with no testing worth the name. Agencies giving that approval are infested with Big Pharma-connected place-people and they act in the interests of Big Pharma (the Cult) and not the public about whom they do not give a damn.

More human lab rats

'Covid vaccines' produced in record time by Pfizer/BioNTech and Moderna employ a technique *never approved before for use on humans*. They are known as mRNA 'vaccines' and inject a synthetic version of 'viral' mRNA or 'messenger RNA'. The key is in the term 'messenger'. The body works, or doesn't, on the basis of information messaging. Communications are constantly passing between and within the genetic system and the brain. Change those messages and you change the state of the body and even its very nature and you can change psychology and behaviour by the way the brain processes information. I think you are going to see significant changes in personality and perception of many people who have had the 'Covid vaccine' synthetic potions. Insider Aldous Huxley predicted the following in 1961 and mRNA 'vaccines' can be included in the term 'pharmacological methods':

> There will be, in the next generation or so, a pharmacological method of making people love their servitude, and producing dictatorship without tears, so to speak, producing a kind of painless concentration camp for entire societies, so that people will in fact have their own liberties taken away from them, but rather enjoy it, because they will be distracted from any desire to rebel by propaganda or brainwashing, or brainwashing enhanced by pharmacological methods. And this seems to be the final revolution.

Apologists claim that mRNA synthetic 'vaccines' don't change the DNA genetic blueprint because RNA does not affect DNA only the other way round. This is so disingenuous. A process called 'reverse

transcription' can convert RNA into DNA and be integrated into DNA in the cell nucleus. This was highlighted in December, 2020, by scientists at Harvard and Massachusetts Institute of Technology (MIT). Geneticists report that more than 40 percent of mammalian genomes results from reverse transcription. On the most basic level if messaging changes then that sequence must lead to changes in DNA which is receiving and transmitting those communications. How can introducing synthetic material into cells not change the cells where DNA is located? The process is known as transfection which is defined as 'a technique to insert foreign nucleic acid (DNA or RNA) into a cell, typically with the intention of altering the properties of the cell'. Researchers at the Sloan Kettering Institute in New York found that changes in messenger RNA can deactivate tumour-suppressing proteins and thereby promote cancer. This is what happens when you mess with messaging. 'Covid vaccine' maker Moderna was founded in 2010 by Canadian stem cell biologist Derrick J. Rossi after his breakthrough discovery in the field of transforming and reprogramming stem cells. These are neutral cells that can be programmed to become any cell including sperm cells. Moderna was therefore founded on the principle of genetic manipulation and has never produced any vaccine or drug before its genetically-manipulating synthetic 'Covid' shite. Look at the name – Mode-RNA or Modify-RNA. Another important point is that the US Supreme Court has ruled that genetically-modified DNA, or complementary DNA (cDNA) synthesized in the laboratory from messenger RNA, can be patented and owned. These psychopaths are doing this to the human body.

Cells replicate synthetic mRNA in the 'Covid vaccines' and in theory the body is tricked into making antigens which trigger antibodies to target the 'virus spike proteins' which as Dr Tom Cowan said have *never been seen*. Cut the crap and these 'vaccines' deliver *self-replicating* synthetic material to the cells with the effect of changing human DNA. The more of them you have the more that process is compounded while synthetic material is all the time self-replicating. 'Vaccine'-maker Moderna describes mRNA as 'like

software for the cell' and so they are messing with the body's software. What happens when you change the software in a computer? Everything changes. For this reason the Cult is preparing a production line of mRNA 'Covid vaccines' and a long list of excuses to use them as with all the 'variants' of a 'virus' never shown to exist. The plan is further to transfer the mRNA technique to other vaccines mostly given to children and young people. The cumulative consequences will be a transformation of human DNA through a constant infusion of synthetic genetic material which will kill many and change the rest. Now consider that governments that have given emergency approval for a vaccine that's not a vaccine; never been approved for humans before; had no testing worth the name; and the makers have been given immunity from prosecution for any deaths or adverse effects suffered by the public. The UK government awarded *permanent legal indemnity* to itself and its employees for harm done when a patient is being treated for 'Covid-19' or 'suspected Covid-19'. That is quite a thought when these are possible 'side-effects' from the 'vaccine' (they are not 'side', they are effects) listed by the US Food and Drug Administration:

Guillain-Barre syndrome; acute disseminated encephalomyelitis; transverse myelitis; encephalitis; myelitis; encephalomyelitis; meningoencephalitis; meningitis; encephalopathy; convulsions; seizures; stroke; narcolepsy; cataplexy; anaphylaxis; acute myocardial infarction (heart attack); myocarditis; pericarditis; autoimmune disease; death; implications for pregnancy, and birth outcomes; other acute demyelinating diseases; non anaphylactic allergy reactions; thrombocytopenia ; disseminated intravascular coagulation; venous thromboembolism; arthritis; arthralgia; joint pain; Kawasaki disease; multisystem inflammatory syndrome in children; vaccine enhanced disease. The latter is the way the 'vaccine' has the potential to make diseases far worse than they would otherwise be.

UK doctor and freedom campaigner Vernon Coleman described the conditions in this list as 'all unpleasant, most of them very serious, and you can't get more serious than death'. The thought that anyone at all has had the 'vaccine' in these circumstances is testament to the potential that humanity has for clueless, unquestioning, stupidity and for many that programmed stupidity has already been terminal.

An insider speaks

Dr Michael Yeadon is a former Vice President, head of research and Chief Scientific Adviser at vaccine giant Pfizer. Yeadon worked on the inside of Big Pharma, but that did not stop him becoming a vocal critic of 'Covid vaccines' and their potential for multiple harms, including infertility in women. By the spring of 2021 he went much further and even used the no, no, term 'conspiracy'. When you begin to see what is going on it is impossible not to do so. Yeadon spoke out in an interview with freedom campaigner James Delingpole and I mentioned earlier how he said that no one had samples of 'the virus'. He explained that the mRNA technique originated in the anti-cancer field and ways to turn on and off certain genes which could be advantageous if you wanted to stop cancer growing out of control. 'That's the origin of them. They are a very unusual application, really.' Yeadon said that treating a cancer patient with an aggressive procedure might be understandable if the alternative was dying, but it was quite another thing to use the same technique as a public health measure. Most people involved wouldn't catch the infectious agent you were vaccinating against and if they did they probably wouldn't die:

> If you are really using it as a public health measure you really want to as close as you can get to zero sides-effects … I find it odd that they chose techniques that were really cutting their teeth in the field of oncology and I'm worried that in using gene-based vaccines that have to be injected in the body and spread around the body, get taken up into some cells, and the regulators haven't quite told us which cells they get taken up into … you are going to be generating a wide range of responses … with multiple steps each of which could go well or badly.

I doubt the Cult intends it to go well. Yeadon said that you can put any gene you like into the body through the 'vaccine'. 'You can certainly give them a gene that would do them some harm if you wanted.' I was intrigued when he said that when used in the cancer field the technique could turn genes on and off. I explore this process in *The Answer* and with different genes having different functions you could create mayhem – physically and psychologically – if you turned the wrong ones on and the right ones off. I read reports of an experiment by researchers at the University of Washington's school of computer science and engineering in which they encoded DNA to infect computers. The body is itself a biological computer and if human DNA can inflict damage on a computer why can't the computer via synthetic material mess with the human body? It can. The Washington research team said it was possible to insert malicious malware into 'physical DNA strands' and corrupt the computer system of a gene sequencing machine as it 'reads gene letters and stores them as binary digits 0 and 1'. They concluded that hackers could one day use blood or spit samples to access computer systems and obtain sensitive data from police forensics labs or infect genome files. It is at this level of digital interaction that synthetic 'vaccines' need to be seen to get the full picture and that will become very clear later on. Michael Yeadon said it made no sense to give the 'vaccine' to younger people who were in no danger from the 'virus'. What was the benefit? It was all downside with potential effects:

> The fact that my government in what I thought was a civilised, rational country, is raining [the 'vaccine'] on people in their 30s and 40s, even my children in their 20s, they're getting letters and phone calls, I know this is not right and any of you doctors who are vaccinating you know it's not right, too. They are not at risk. They are not at risk from the disease, so you are now hoping that the side-effects are so rare that you get away with it. You don't give new technology … that you don't understand to 100 percent of the population.

Blood clot problems with the AstraZeneca 'vaccine' have been affecting younger people to emphasise the downside risks with no benefit. AstraZeneca's version, produced with Oxford University, does not use mRNA, but still gets its toxic cocktail inside cells where

it targets DNA. The Johnson & Johnson 'vaccine' which uses a similar technique has also produced blood clot effects to such an extent that the United States paused its use at one point. They are all 'gene therapy' (cell modification) procedures and not 'vaccines'. The truth is that once the content of these injections enter cells we have no idea what the effect will be. People can speculate and some can give very educated opinions and that's good. In the end, though, only the makers know what their potions are designed to do and even they won't know every last consequence. Michael Yeadon was scathing about doctors doing what they knew to be wrong. 'Everyone's mute', he said. Doctors in the NHS must know this was not right, coming into work and injecting people. 'I don't know how they sleep at night. I know I couldn't do it. I know that if I were in that position I'd have to quit.' He said he knew enough about toxicology to know this was not a good risk-benefit. Yeadon had spoken to seven or eight university professors and all except two would not speak out publicly. Their universities had a policy that no one said anything that countered the government and its medical advisors. They were afraid of losing their government grants. This is how intimidation has been used to silence the truth at every level of the system. I say silence, but these people could still speak out if they made that choice. Yeadon called them 'moral cowards' – 'This is about your children and grandchildren's lives and you have just buggered off and left it.'

'Variant' nonsense

Some of his most powerful comments related to the alleged 'variants' being used to instil more fear, justify more lockdowns, and introduce more 'vaccines'. He said government claims about 'variants' were nonsense. He had checked the alleged variant 'codes' and they were 99.7 percent identical to the 'original'. This was the human identity difference equivalent to putting a baseball cap on and off or wearing it the other way round. A 0.3 percent difference would make it impossible for that 'variant' to escape immunity from the 'original'. This made no sense of having new 'vaccines' for

'variants'. He said there would have to be at least a *30 percent* difference for that to be justified and even then he believed the immune system would still recognise what it was. Gates-funded 'variant modeller' and 'vaccine'-pusher John Edmunds might care to comment. Yeadon said drug companies were making new versions of the 'vaccine' as a 'top up' for 'variants'. Worse than that, he said, the 'regulators' around the world like the MHRA in the UK had got together and agreed that because 'vaccines' for 'variants' were so similar to the first 'vaccines' *they did not have to do safety studies*. How transparently sinister that is. This is when Yeadon said: 'There is a conspiracy here.' There was no need for another vaccine for 'variants' and yet we were told that there was and the country had shut its borders because of them. 'They are going into hundreds of millions of arms without passing 'go' or any regulator. Why did they do that? Why did they pick this method of making the vaccine?'

The reason had to be something bigger than that it seemed and 'it's not protection against the virus'. It's was a far bigger project that meant politicians and advisers were willing to do things and not do things that knowingly resulted in avoidable deaths – 'that's already happened when you think about lockdown and deprivation of health care for a year.' He spoke of people prepared to do something that results in the avoidable death of their fellow human beings and it not bother them. This is the penny-drop I have been working to get across for more than 30 years – the level of pure evil we are dealing with. Yeadon said his friends and associates could not believe there could be that much evil, but he reminded them of Stalin, Pol Pot and Hitler and of what Stalin had said: 'One death is a tragedy. A million? A statistic.' He could not think of a benign explanation for why you need top-up vaccines 'which I'm sure you don't' and for the regulators 'to just get out of the way and wave them through'. Why would the regulators do that when they were still wrestling with the dangers of the 'parent' vaccine? He was clearly shocked by what he had seen since the 'Covid' hoax began and now he was thinking the previously unthinkable:

If you wanted to depopulate a significant proportion of the world and to do it in a way that doesn't involve destruction of the environment with nuclear weapons, poisoning everyone with anthrax or something like that, and you wanted plausible deniability while you had a multi-year infectious disease crisis, I actually don't think you could come up with a better plan of work than seems to be in front of me. I can't say that's what they are going to do, but I can't think of a benign explanation why they are doing it.

He said he never thought that they would get rid of 99 percent of humans, but now he wondered. 'If you wanted to that this would be a hell of a way to do it – it would be unstoppable folks.' Yeadon had concluded that those who submitted to the 'vaccine' would be allowed to have some kind of normal life (but for how long?) while screws were tightened to coerce and mandate the last few percent. 'I think they'll put the rest of them in a prison camp. I wish I was wrong, but I don't think I am.' Other points he made included: There were no coronavirus vaccines then suddenly they all come along at the same time; we have no idea of the long term affect with trials so short; coercing or forcing people to have medical procedures is against the Nuremberg Code instigated when the Nazis did just that; people should at least delay having the 'vaccine'; a quick Internet search confirms that masks don't reduce respiratory viral transmission and 'the government knows that'; they have smashed civil society and they know that, too; two dozen peer-reviewed studies show no connection between lockdown and reducing deaths; he knew from personal friends the elite were still flying around and going on holiday while the public were locked down; the elite were not having the 'vaccines'. He was also asked if 'vaccines' could be made to target difference races. He said he didn't know, but the document by the Project for the New American Century in September, 2000, said developing 'advanced forms of biological warfare that can target *specific genotypes* may transform biological warfare from the realm of terror to a politically useful tool.' Oh, they're evil all right. Of that we can be *absolutely* sure.

Another cull of old people

We have seen from the CDC definition that the mRNA 'Covid vaccine' is not a vaccine and nor are the others that *claim* to reduce 'severity of symptoms' in *some* people, but not protect from infection or transmission. What about all the lies about returning to 'normal' if people were 'vaccinated'? If they are not claimed to stop infection and transmission of the alleged 'virus', how does anything change? This was all lies to manipulate people to take the jabs and we are seeing that now with masks and distancing still required for the 'vaccinated'. How did they think that elderly people with fragile health and immune responses were going to be affected by infusing their cells with synthetic material and other toxic substances? They *knew* that in the short and long term it would be devastating and fatal as the culling of the old that began with the first lockdowns was continued with the 'vaccine'. Death rates in care homes soared immediately residents began to be 'vaccinated' – infused with synthetic material. Brave and committed whistleblower nurses put their careers at risk by exposing this truth while the rest kept their heads down and their mouths shut to put their careers before those they are supposed to care for. A long-time American Certified Nursing Assistant who gave his name as James posted a video in which he described emotionally what happened in his care home when vaccination began. He said that during 2020 very few residents were sick with 'Covid' and no one died during the entire year; but shortly after the Pfizer mRNA injections 14 people died within two weeks and many others were near death. 'They're dropping like flies', he said. Residents who walked on their own before the shot could no longer and they had lost their ability to conduct an intelligent conversation. The home's management said the sudden deaths were caused by a 'super-spreader' of 'Covid-19'. Then how come, James asked, that residents who refused to take the injections were not sick? It was a case of inject the elderly with mRNA synthetic potions and blame their illness and death that followed on the 'virus'. James described what was happening in care homes as 'the greatest crime of genocide this country has ever seen'. Remember the NHS staff nurse from earlier who used the same

word ‘genocide’ for what was happening with the ‘vaccines’ and that it was an ‘act of human annihilation’. A UK care home whistleblower told a similar story to James about the effect of the ‘vaccine’ in deaths and ‘outbreaks’ of illness dubbed ‘Covid’ after getting the jab. She told how her care home management and staff had zealously imposed government regulations and no one was allowed to even question the official narrative let alone speak out against it. She said the NHS was even worse. Again we see the results of reframing. A worker at a local care home where I live said they had not had a single case of ‘Covid’ there for almost a year and when the residents were ‘vaccinated’ they had 19 positive cases in two weeks with eight dying.

It’s not the ‘vaccine’ – honest

The obvious cause and effect was being ignored by the media and most of the public. Australia’s health minister Greg Hunt (a former head of strategy at the World Economic Forum) was admitted to hospital after he had the ‘vaccine’. He was suffering according to reports from the skin infection ‘cellulitis’ and it must have been a severe case to have warranted days in hospital. Immediately the authorities said this was nothing to do with the ‘vaccine’ when an effect of some vaccines is a ‘cellulitis-like reaction’. We had families of perfectly healthy old people who died after the ‘vaccine’ saying that if only they had been given the ‘vaccine’ earlier they would still be alive. As a numbskull rating that is off the chart. A father of four ‘died of Covid’ at aged 48 when he was taken ill two days after having the ‘vaccine’. The man, a health administrator, had been ‘shielding during the pandemic’ and had ‘not really left the house’ until he went for the ‘vaccine’. Having the ‘vaccine’ and then falling ill and dying does not seem to have qualified as a possible cause and effect and ‘Covid-19’ went on his death certificate. His family said they had no idea how he ‘caught the virus’. A family member said: ‘Tragically, it could be that going for a vaccination ultimately led to him catching Covid …The sad truth is that they are never going to know where it came from.’ The family warned people to remember

that the virus still existed and was 'very real'. So was their stupidity. Nurses and doctors who had the first round of the 'vaccine' were collapsing, dying and ending up in a hospital bed while they or their grieving relatives were saying they'd still have the 'vaccine' again despite what happened. I kid you not. You mean if your husband returned from the dead he'd have the same 'vaccine' again that killed him??

Doctors at the VCU Medical Center in Richmond, Virginia, said the Johnson & Johnson 'vaccine' was to blame for a man's skin peeling off. Patient Richard Terrell said: 'It all just happened so fast. My skin peeled off. It's still coming off on my hands now.' He said it was stinging, burning and itching and when he bent his arms and legs it was very painful with 'the skin swollen and rubbing against itself'. Pfizer/BioNTech and Moderna vaccines use mRNA to change the cell while the Johnson & Johnson version uses DNA in a process similar to AstraZeneca's technique. Johnson & Johnson and AstraZeneca have both had their 'vaccines' paused by many countries after causing serious blood problems. Terrell's doctor Fnu Nutan said he could have died if he hadn't got medical attention. It sounds terrible so what did Nutan and Terrell say about the 'vaccine' now? Oh, they still recommend that people have it. A nurse in a hospital bed 40 minutes after the vaccination and unable to swallow due to throat swelling was told by a doctor that he lost mobility in his arm for 36 hours following the vaccination. What did he say to the ailing nurse? 'Good for you for getting the vaccination.' We are dealing with a serious form of cognitive dissonance madness in both public and medical staff. There is a remarkable correlation between those having the 'vaccine' and trumpeting the fact and suffering bad happenings shortly afterwards. Witold Rogiewicz, a Polish doctor, made a video of his 'vaccination' and ridiculed those who were questioning its safety and the intentions of Bill Gates: 'Vaccinate yourself to protect yourself, your loved ones, friends and also patients. And to mention quickly I have info for anti-vaxxers and anti-Coviders if you want to contact Bill Gates you can do this through me.' He further ridiculed the dangers of 5G. Days later he

was dead, but naturally the vaccination wasn't mentioned in the verdict of 'heart attack'.

Lies, lies and more lies

So many members of the human race have slipped into extreme states of insanity and unfortunately they include reframed doctors and nursing staff. Having a 'vaccine' and dying within minutes or hours is not considered a valid connection while death from any cause within 28 days or longer of a positive test with a test not testing for the 'virus' means 'Covid-19' goes on the death certificate. How could that 'vaccine'-death connection not have been made except by calculated deceit? US figures in the initial rollout period to February 12th, 2020, revealed that a third of the deaths reported to the CDC after 'Covid vaccines' happened within 48 hours. Five men in the UK suffered an 'extremely rare' blood clot problem after having the AstraZeneca 'vaccine', but no causal link was established said the Gates-funded Medicines and Healthcare products Regulatory Agency (MHRA) which had given the 'vaccine' emergency approval to be used. Former Pfizer executive Dr Michael Yeadon explained in his interview how the procedures could cause blood coagulation and clots. People who should have been at no risk were dying from blood clots in the brain and he said he had heard from medical doctor friends that people were suffering from skin bleeding and massive headaches. The AstraZeneca 'shot' was stopped by some 20 countries over the blood clotting issue and still the corrupt MHRA, the European Medicines Agency (EMA) and the World Health Organization said that it should continue to be given even though the EMA admitted that it 'still cannot rule out definitively' a link between blood clotting and the 'vaccine'. Later Marco Cavaleri, head of EMA vaccine strategy, said there was indeed a clear link between the 'vaccine' and thrombosis, but they didn't know why. So much for the trials showing the 'vaccine' is safe. Blood clots were affecting younger people who would be under virtually no danger from 'Covid' even if it existed which makes it all the more stupid and sinister.

The British government responded to public alarm by wheeling out June Raine, the terrifyingly weak infant school headmistress sound-alike who heads the UK MHRA drug 'regulator'. The idea that she would stand up to Big Pharma and government pressure is laughable and she told us that all was well in the same way that she did when allowing untested, never-used-on-humans-before, genetically-manipulating 'vaccines' to be exposed to the public in the first place. Mass lying is the new normal of the 'Covid' era. The MHRA later said 30 cases of rare blood clots had by then been connected with the AstraZeneca 'vaccine' (that means a lot more in reality) while stressing that the benefits of the jab in preventing 'Covid-19' outweighed any risks. A more ridiculous and disingenuous statement with callous disregard for human health it is hard to contemplate. Immediately after the mendacious 'all-clears' two hospital workers in Denmark experienced blood clots and cerebral haemorrhaging following the AstraZeneca jab and one died. Top Norwegian health official Pål Andre Holme said the 'vaccine' was the only common factor: 'There is nothing in the patient history of these individuals that can give such a powerful immune response … I am confident that the antibodies that we have found are the cause, and I see no other explanation than it being the vaccine which triggers it.' Strokes, a clot or bleed in the brain, were clearly associated with the 'vaccine' from word of mouth and whistleblower reports. Similar consequences followed with all these 'vaccines' that we were told were so safe and as the numbers grew by the day it was clear we were witnessing human carnage.

Learning the hard way

A woman interviewed by UKColumn told how her husband suffered dramatic health effects after the vaccine when he'd been in good health all his life. He went from being a little unwell to losing all feeling in his legs and experiencing 'excruciating pain'. Misdiagnosis followed twice at Accident and Emergency (an 'allergy' and 'sciatica') before he was admitted to a neurology ward where doctors said his serious condition had been caused by the

'vaccine'. Another seven 'vaccinated' people were apparently being treated on the same ward for similar symptoms. The woman said he had the 'vaccine' because they believed media claims that it was safe. 'I didn't think the government would give out a vaccine that does this to somebody; I believed they would be bringing out a vaccination that would be safe.' What a tragic way to learn that lesson. Another woman posted that her husband was transporting stroke patients to hospital on almost every shift and when he asked them if they had been 'vaccinated' for 'Covid' they all replied 'yes'. One had a 'massive brain bleed' the day after his second dose. She said her husband reported the 'just been vaccinated' information every time to doctors in A and E only for them to ignore it, make no notes and appear annoyed that it was even mentioned. This particular report cannot be verified, but it expresses a common theme that confirms the monumental underreporting of 'vaccine' consequences. Interestingly as the 'vaccines' and their brain blood clot/stroke consequences began to emerge the UK National Health Service began a publicity campaign telling the public what to do in the event of a stroke. A Scottish NHS staff nurse who quit in disgust in March, 2021, said:

I have seen traumatic injuries from the vaccine, they're not getting reported to the yellow card [adverse reaction] scheme, they're treating the symptoms, not asking why, why it's happening. It's just treating the symptoms and when you speak about it you're dismissed like you're crazy, I'm not crazy, I'm not crazy because every other colleague I've spoken to is terrified to speak out, they've had enough.

Videos appeared on the Internet of people uncontrollably shaking after the 'vaccine' with no control over muscles, limbs and even their face. A Scottish mother broke out in a severe rash all over her body almost immediately after she was given the AstraZeneca 'vaccine'. The pictures were horrific. Leigh King, a 41-year-old hairdresser from Lanarkshire said: 'Never in my life was I prepared for what I was about to experience … My skin was so sore and constantly hot … I have never felt pain like this …' But don't you worry, the 'vaccine' is perfectly safe. Then there has been the effect on medical

staff who have been pressured to have the 'vaccine' by psychopathic 'health' authorities and government. A London hospital consultant who gave the name K. Polyakova wrote this to the *British Medical Journal* or *BMJ*:

> I am currently struggling with … the failure to report the reality of the morbidity caused by our current vaccination program within the health service and staff population. The levels of sickness after vaccination is unprecedented and staff are getting very sick and some with neurological symptoms which is having a huge impact on the health service function. Even the young and healthy are off for days, some for weeks, and some requiring medical treatment. Whole teams are being taken out as they went to get vaccinated together.
>
> Mandatory vaccination in this instance is stupid, unethical and irresponsible when it comes to protecting our staff and public health. We are in the voluntary phase of vaccination, and encouraging staff to take an unlicensed product that is impacting on their immediate health … it is clearly stated that these vaccine products do not offer immunity or stop transmission. In which case why are we doing it?

Not to protect health that's for sure. Medical workers are lauded by governments for agenda reasons when they couldn't give a toss about them any more than they can for the population in general. Schools across America faced the same situation as they closed due to the high number of teachers and other staff with bad reactions to the Pfizer/BioNTech, Moderna, and Johnson & Johnson 'Covid vaccines' all of which were linked to death and serious adverse effects. The *BMJ* took down the consultant's comments pretty quickly on the grounds that they were being used to spread 'disinformation'. They were exposing the truth about the 'vaccine' was the real reason. The cover-up is breathtaking.

Hiding the evidence

The scale of the 'vaccine' death cover-up worldwide can be confirmed by comparing official figures with the personal experience of the public. I heard of many people in my community who died immediately or soon after the vaccine that would never appear in the media or even likely on the official totals of 'vaccine' fatalities and adverse reactions when only about ten percent are estimated to be

reported and I have seen some estimates as low as one percent in a Harvard study. In the UK alone by April 29th, 2021, some 757,654 adverse reactions had been officially reported from the Pfizer/BioNTech, Oxford/AstraZeneca and Moderna 'vaccines' with more than a thousand deaths linked to jabs and that means an estimated ten times this number in reality from a ten percent reporting rate percentage. That's seven million adverse reactions and 10,000 potential deaths and a one percent reporting rate would be ten times *those* figures. In 1976 the US government pulled the swine flu vaccine after *53* deaths. The UK data included a combined 10,000 eye disorders from the 'Covid vaccines' with more than 750 suffering visual impairment or blindness and again multiply by the estimated reporting percentages. As 'Covid cases' officially fell hospitals virtually empty during the 'Covid crisis' began to fill up with a range of other problems in the wake of the 'vaccine' rollout. The numbers across America have also been catastrophic. Deaths linked to *all* types of vaccine increased by *6,000 percent* in the first quarter of 2021 compared with 2020. A 39-year-old woman from Ogden, Utah, died four days after receiving a second dose of Moderna's 'Covid vaccine' when her liver, heart and kidneys all failed despite the fact that she had no known medical issues or conditions. Her family sought an autopsy, but Dr Erik Christensen, Utah's chief medical examiner, said proving vaccine injury as a cause of death almost never happened. He could think of only one instance where an autopsy would name a vaccine as the official cause of death and that would be anaphylaxis where someone received a vaccine and died almost instantaneously. 'Short of that, it would be difficult for us to definitively say this is the vaccine,' Christensen said. If that is true this must be added to the estimated ten percent (or far less) reporting rate of vaccine deaths and serious reactions and the conclusion can only be that vaccine deaths and serious reactions – including these 'Covid' potions' – are phenomenally understated in official figures. The same story can be found everywhere. Endless accounts of deaths and serious reactions among the public, medical

and care home staff while official figures did not even begin to reflect this.

Professional script-reader Dr David Williams, a 'top public-health official' in Ontario, Canada, insulted our intelligence by claiming only four serious adverse reactions and no deaths from the more than 380,000 vaccine doses then given. This bore no resemblance to what people knew had happened in their owns circles and we had Dirk Huyer in charge of getting millions vaccinated in Ontario while at the same time he was Chief Coroner for the province investigating causes of death including possible death from the vaccine. An aide said he had stepped back from investigating deaths, but evidence indicated otherwise. Rosemary Frei, who secured a Master of Science degree in molecular biology at the Faculty of Medicine at Canada's University of Calgary before turning to investigative journalism, was one who could see that official figures for 'vaccine' deaths and reactions made no sense. She said that doctors seldom reported adverse events and when people got really sick or died after getting a vaccination they would attribute that to anything except the vaccines. It had been that way for years and anyone who wondered aloud whether the 'Covid vaccines' or other shots cause harm is immediately branded as 'anti-vax' and 'anti-science'. This was 'career-threatening' for health professionals. Then there was the huge pressure to support the push to 'vaccinate' billions in the quickest time possible. Frei said:

> So that's where we're at today. More than half a million vaccine doses have been given to people in Ontario alone. The rush is on to vaccinate all 15 million of us in the province by September. And the mainstream media are screaming for this to be sped up even more. That all adds up to only a very slim likelihood that we're going to be told the truth by officials about how many people are getting sick or dying from the vaccines.

What is true of Ontario is true of everywhere.

They KNEW – and still did it

The authorities knew what was going to happen with multiple deaths and adverse reactions. The UK government's Gates-funded

and Big Pharma-dominated Medicines and Healthcare products Regulatory Agency (MHRA) hired a company to employ AI in compiling the projected reactions to the 'vaccine' that would otherwise be uncountable. The request for applications said: 'The MHRA urgently seeks an Artificial Intelligence (AI) software tool to process the expected high volume of Covid-19 vaccine Adverse Drug Reaction …' This was from the agency, headed by the disingenuous June Raine, that gave the 'vaccines' emergency approval and the company was hired before the first shot was given. 'We are going to kill and maim you – is that okay?' 'Oh, yes, perfectly fine – I'm very grateful, thank you, doctor.' The range of 'Covid vaccine' adverse reactions goes on for page after page in the MHRA criminally underreported 'Yellow Card' system and includes affects to eyes, ears, skin, digestion, blood and so on. Raine's MHRA amazingly claimed that the 'overall safety experience … is so far as expected from the clinical trials'. The death, serious adverse effects, deafness and blindness were *expected?* When did they ever mention that? If these human tragedies were expected then those that gave approval for the use of these 'vaccines' must be guilty of crimes against humanity including murder – a definition of which is 'killing a person with malice aforethought or with recklessness manifesting extreme indifference to the value of human life.' People involved at the MHRA, the CDC in America and their equivalent around the world must go before Nuremberg trials to answer for their callous inhumanity. We are only talking here about the immediate effects of the 'vaccine'. The longer-term impact of the DNA synthetic manipulation is the main reason they are so hysterically desperate to inoculate the entire global population in the shortest possible time.

Africa and the developing world are a major focus for the 'vaccine' depopulation agenda and a mass vaccination sales-pitch is underway thanks to caring people like the Rockefellers and other Cult assets. The Rockefeller Foundation, which pre-empted the 'Covid pandemic' in a document published in 2010 that 'predicted' what happened a decade later, announced an initial $34.95 million grant in February, 2021, 'to ensure more equitable access to Covid-19

testing and vaccines' among other things in Africa in collaboration with '24 organizations, businesses, and government agencies'. The pan-Africa initiative would focus on 10 countries: Burkina Faso, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, South Africa, Tanzania, Uganda, and Zambia'. Rajiv Shah, President of the Rockefeller Foundation and former administrator of CIA-controlled USAID, said that if Africa was not mass-vaccinated (to change the DNA of its people) it was a 'threat to all of humanity' and not fair on Africans. When someone from the Rockefeller Foundation says they want to do something to help poor and deprived people and countries it is time for a belly-laugh. They are doing this out of the goodness of their 'heart' because 'vaccinating' the entire global population is what the 'Covid' hoax set out to achieve. Official 'decolonisation' of Africa by the Cult was merely a prelude to financial colonisation on the road to a return to physical colonisation. The 'vaccine' is vital to that and the sudden and convenient death of the 'Covid' sceptic president of Tanzania can be seen in its true light. A lot of people in Africa are aware that this is another form of colonisation and exploitation and they need to stand their ground.

The 'vaccine is working' scam

A potential problem for the Cult was that the 'vaccine' is meant to change human DNA and body messaging and not to protect anyone from a 'virus' never shown to exist. The vaccine couldn't work because it was not designed to work and how could they make it *appear* to be working so that more people would have it? This was overcome by lowering the amplification rate of the PCR test to produce fewer 'cases' and therefore fewer 'deaths'. Some of us had been pointing out since March, 2020, that the amplification rate of the test not testing for the 'virus' had been made artificially high to generate positive tests which they could call 'cases' to justify lockdowns. The World Health Organization recommended an absurdly high 45 amplification cycles to ensure the high positives required by the Cult and then remained silent on the issue until January 20th, 2021 – Biden's Inauguration Day. This was when the

'vaccinations' were seriously underway and on that day the WHO recommended after discussions with America's CDC that laboratories *lowered their testing amplification*. Dr David Samadi, a certified urologist and health writer, said the WHO was encouraging all labs to reduce their cycle count for PCR tests. He said the current cycle was much too high and was 'resulting in any particle being declared a positive case'. Even one mainstream news report I saw said this meant the number of 'Covid' infections may have been 'dramatically inflated'. Oh, just a little bit. The CDC in America issued new guidance to laboratories in April, 2021, to use 28 cycles *but only for 'vaccinated' people*. The timing of the CDC/WHO interventions were cynically designed to make it appear the 'vaccines' were responsible for falling cases and deaths when the real reason can be seen in the following examples. New York's state lab, the Wadsworth Center, identified 872 positive tests in July, 2020, based on a threshold of 40 cycles. When the figure was lowered to 35 cycles *43 percent* of the 872 were no longer 'positives'. At 30 cycles the figure was 63 percent. A Massachusetts lab found that between *85 to 90 percent* of people who tested positive in July with a cycle threshold of 40 would be negative at 30 cycles, Ashish Jha, MD, director of the Harvard Global Health Institute, said: 'I'm really shocked that it could be that high … Boy, does it really change the way we need to be thinking about testing.' I'm shocked that I could see the obvious in the spring of 2020, with no medical background, and most medical professionals still haven't worked it out. No, that's not shocking – it's terrifying.

Three weeks after the WHO directive to lower PCR cycles the London *Daily Mail* ran this headline: 'Why ARE Covid cases plummeting? New infections have fallen 45% in the US and 30% globally in the past 3 weeks but experts say vaccine is NOT the main driver because only 8% of Americans and 13% of people worldwide have received their first dose.' They acknowledged that the drop could not be attributed to the 'vaccine', but soon this morphed throughout the media into the 'vaccine' has caused cases and deaths to fall when it was the PCR threshold. In December, 2020, there was

chaos at English Channel ports with truck drivers needing negative 'Covid' tests before they could board a ferry home for Christmas. The government wanted to remove the backlog as fast as possible and they brought in troops to do the 'testing'. Out of 1,600 drivers just *36* tested positive and the rest were given the all clear to cross the Channel. I guess the authorities thought that 36 was the least they could get away with without the unquestioning catching on. The amplification trick which most people believed in the absence of information in the mainstream applied more pressure on those refusing the 'vaccine' to succumb when it 'obviously worked'. The truth was the exact opposite with deaths in care homes soaring with the 'vaccine' and in Israel the term used was 'skyrocket'. A re-analysis of published data from the Israeli Health Ministry led by Dr Hervé Seligmann at the Medicine Emerging Infectious and Tropical Diseases at Aix-Marseille University found that Pfizer's 'Covid vaccine' killed 'about 40 times more [elderly] people than the disease itself would have killed' during a five-week vaccination period and *260 times* more younger people than would have died from the 'virus' even according to the manipulated 'virus' figures. Dr Seligmann and his co-study author, Haim Yativ, declared after reviewing the Israeli 'vaccine' death data: 'This is a new Holocaust.'

Then, in mid-April, 2021, after vast numbers of people worldwide had been 'vaccinated', the story changed with clear coordination. The UK government began to prepare the ground for more future lockdowns when Nuremberg-destined Boris Johnson told yet another whopper. He said that cases had fallen because of *lockdowns* not 'vaccines'. Lockdowns are irrelevant when *there is no 'virus'* and the test and fraudulent death certificates are deciding the number of 'cases' and 'deaths'. Study after study has shown that lockdowns don't work and instead kill and psychologically destroy people. Meanwhile in the United States Anthony Fauci and Rochelle Walensky, the ultra-Zionist head of the CDC, peddled the same line. More lockdown was the answer and not the 'vaccine', a line repeated on cue by the moron that is Canadian Prime Minister Justin Trudeau. Why all the hysteria to get everyone 'vaccinated' if lockdowns and

not 'vaccines' made the difference? None of it makes sense on the face of it. Oh, but it does. The Cult wants lockdowns *and* the 'vaccine' and if the 'vaccine' is allowed to be seen as the total answer lockdowns would no longer be justified when there are still livelihoods to destroy. 'Variants' and renewed upward manipulation of PCR amplification are planned to instigate never-ending lockdown *and* more 'vaccines'.

You *must* have it – we're desperate

Israel, where the Jewish and Arab population are ruled by the Sabbatian Cult, was the front-runner in imposing the DNA-manipulating 'vaccine' on its people to such an extent that Jewish refusers began to liken what was happening to the early years of Nazi Germany. This would seem to be a fantastic claim. Why would a government of Jewish people be acting like the Nazis did? If you realise that the Sabbatian Cult was behind the Nazis and that Sabbatians hate Jews the pieces start to fit and the question of why a 'Jewish' government would treat Jews with such callous disregard for their lives and freedom finds an answer. Those controlling the government of Israel *aren't Jewish* – they're Sabbatian. Israeli lawyer Tamir Turgal was one who made the Nazi comparison in comments to German lawyer Reiner Fuellmich who is leading a class action lawsuit against the psychopaths for crimes against humanity. Turgal described how the Israeli government was vaccinating children and pregnant women on the basis that there was no evidence that this was dangerous when they had no evidence that it *wasn't* dangerous either. They just had no evidence. This was medical experimentation and Turgal said this breached the Nuremberg Code about medical experimentation and procedures requiring informed consent and choice. Think about that. A Nuremberg Code developed because of Nazi experimentation on Jews and others in concentration camps by people like the evil-beyond-belief Josef Mengele is being breached by the *Israeli* government; but when you know that it's a *Sabbatian* government along with its intelligence and military agencies like Mossad, Shin Bet and the Israeli Defense Forces, and that Sabbatians

were the force behind the Nazis, the kaleidoscope comes into focus. What have we come to when Israeli Jews are suing their government for violating the Nuremberg Code by essentially making Israelis subject to a medical experiment using the controversial 'vaccines'? It's a shocker that this has to be done in the light of what happened in Nazi Germany. The Anshe Ha-Emet, or 'People of the Truth', made up of Israeli doctors, lawyers, campaigners and public, have launched a lawsuit with the International Criminal Court. It says:

> When the heads of the Ministry of Health as well as the prime minister presented the vaccine in Israel and began the vaccination of Israeli residents, the vaccinated were not advised, that, in practice, they are taking part in a medical experiment and that their consent is required for this under the Nuremberg Code.

The irony is unbelievable, but easily explained in one word: Sabbatians. The foundation of Israeli 'Covid' apartheid is the 'green pass' or 'green passport' which allows Jews and Arabs who have had the DNA-manipulating 'vaccine' to go about their lives – to work, fly, travel in general, go to shopping malls, bars, restaurants, hotels, concerts, gyms, swimming pools, theatres and sports venues, while non-'vaccinated' are banned from all those places and activities. Israelis have likened the 'green pass' to the yellow stars that Jews in Nazi Germany were forced to wear – the same as the yellow stickers that a branch of UK supermarket chain Morrisons told exempt mask-wears they had to display when shopping. How very sensitive. The Israeli system is blatant South African-style apartheid on the basis of compliance or non-compliance to fascism rather than colour of the skin. How appropriate that the Sabbatian Israeli government was so close to the pre-Mandela apartheid regime in Pretoria. The Sabbatian-instigated 'vaccine passport' in Israel is planned for everywhere. Sabbatians struck a deal with Pfizer that allowed them to lead the way in the percentage of a national population infused with synthetic material and the result was catastrophic. Israeli freedom activist Shai Dannon told me how chairs were appearing on beaches that said 'vaccinated only'. Health Minister Yuli Edelstein said that anyone unwilling or unable to get

the jabs that 'confer immunity' will be 'left behind'. The man's a liar. Not even the makers claim the 'vaccines' confer immunity. When you see those figures of 'vaccine' deaths these psychopaths were saying that you must take the chance the 'vaccine' will kill you or maim you while knowing it will change your DNA or lockdown for you will be permanent. That's fascism. The Israeli parliament passed a law to allow personal information of the non-vaccinated to be shared with local and national authorities for three months. This was claimed by its supporters to be a way to 'encourage' people to be vaccinated. Hadas Ziv from Physicians for Human Rights described this as a 'draconian law which crushed medical ethics and the patient rights'. But that's the idea, the Sabbatians would reply.

Your papers, please

Sabbatian Israel was leading what has been planned all along to be a global 'vaccine pass' called a 'green passport' without which you would remain in permanent lockdown restriction and unable to do anything. This is how badly – *desperately* – the Cult is to get everyone 'vaccinated'. The term and colour 'green' was not by chance and related to the psychology of fusing the perception of the green climate hoax with the 'Covid' hoax and how the 'solution' to both is the same Great Reset. Lying politicians, health officials and psychologists denied there were any plans for mandatory vaccinations or restrictions based on vaccinations, but they knew that was exactly what was meant to happen with governments of all countries reaching agreements to enforce a global system. 'Free' Denmark and 'free' Sweden unveiled digital vaccine certification. Cyprus, Czech Republic, Estonia, Greece, Hungary, Iceland, Italy, Poland, Portugal, Slovakia, and Spain have all committed to a vaccine passport system and the rest including the whole of the EU would follow. The satanic UK government will certainly go this way despite mendacious denials and at the time of writing it is trying to manipulate the public into having the 'vaccine' so they could go abroad on a summer holiday. How would that work without something to prove you had the synthetic toxicity injected into you?

Documents show that the EU's European Commission was moving towards 'vaccine certificates' in 2018 and 2019 before the 'Covid' hoax began. They knew what was coming. Abracadabra – Ursula von der Leyen, the German President of the Commission, announced in March, 2021, an EU 'Digital Green Certificate' – green again – to track the public's 'Covid status'. The passport sting is worldwide and the Far East followed the same pattern with South Korea ruling that only those with 'vaccination' passports – again the *green* pass – would be able to 'return to their daily lives'.

Bill Gates has been preparing for this 'passport' with other Cult operatives for years and beyond the paper version is a Gates-funded 'digital tattoo' to identify who has been vaccinated and who hasn't. The 'tattoo' is reported to include a substance which is externally readable to confirm who has been vaccinated. This is a bio-luminous light-generating enzyme (think fireflies) called … *Luciferase*. Yes, named after the Cult 'god' Lucifer the 'light bringer' of whom more to come. Gates said he funded the readable tattoo to ensure children in the developing world were vaccinated and no one was missed out. He cares so much about poor kids as we know. This was just the cover story to develop a vaccine tagging system for everyone on the planet. Gates has been funding the ID2020 'alliance' to do just that in league with other lovely people at Microsoft, GAVI, the Rockefeller Foundation, Accenture and IDEO.org. He said in interviews in March, 2020, before any 'vaccine' publicly existed, that the world must have a globalised digital certificate to track the 'virus' and who had been vaccinated. Gates knew from the start that the mRNA vaccines were coming and when they would come and that the plan was to tag the 'vaccinated' to marginalise the intelligent and stop them doing anything including travel. Evil just doesn't suffice. Gates was exposed for offering a $10 million bribe to the Nigerian House of Representatives to invoke compulsory 'Covid' vaccination of all Nigerians. Sara Cunial, a member of the Italian Parliament, called Gates a 'vaccine criminal'. She urged the Italian President to hand him over to the International Criminal Court for crimes against

humanity and condemned his plans to 'chip the human race' through ID2020.

You know it's a long-planned agenda when war criminal and Cult gofer Tony Blair is on the case. With the scale of arrogance only someone as dark as Blair can muster he said: 'Vaccination in the end is going to be your route to liberty.' Blair is a disgusting piece of work and he confirms that again. The media has given a lot of coverage to a bloke called Charlie Mullins, founder of London's biggest independent plumbing company, Pimlico Plumbers, who has said he won't employ anyone who has not been vaccinated or have them go to any home where people are not vaccinated. He said that if he had his way no one would be allowed to walk the streets if they have not been vaccinated. Gates was cheering at the time while I was alerting the white coats. The plan is that people will qualify for 'passports' for having the first two doses and then to keep it they will have to have all the follow ups and new ones for invented 'variants' until human genetics is transformed and many are dead who can't adjust to the changes. Hollywood celebrities – the usual propaganda stunt – are promoting something called the WELL Health-Safety Rating to verify that a building or space has 'taken the necessary steps to prioritize the health and safety of their staff, visitors and other stakeholders'. They included Lady Gaga, Jennifer Lopez, Michael B. Jordan, Robert DeNiro, Venus Williams, Wolfgang Puck, Deepak Chopra and 17th Surgeon General Richard Carmona. Yawn. WELL Health-Safety has big connections with China. Parent company Delos is headed by former Goldman Sachs partner Paul Scialla. This is another example – and we will see so many others – of using the excuse of 'health' to dictate the lives and activities of the population. I guess one confirmation of the 'safety' of buildings is that only 'vaccinated' people can go in, right?

Electronic concentration camps

I wrote decades ago about the plans to restrict travel and here we are for those who refuse to bow to tyranny. This can be achieved in one go with air travel if the aviation industry makes a blanket decree.

The ‘vaccine’ and guaranteed income are designed to be part of a global version of China’s social credit system which tracks behaviour 24/7 and awards or deletes ‘credits’ based on whether your behaviour is supported by the state or not. I mean your entire lifestyle – what you do, eat, say, everything. Once your credit score falls below a certain level consequences kick in. In China tens of millions have been denied travel by air and train because of this. All the locations and activities denied to refusers by the ‘vaccine’ passports will be included in one big mass ban on doing almost anything for those that don’t bow their head to government. It’s beyond fascist and a new term is required to describe its extremes – I guess fascist technocracy will have to do. The way the Chinese system of technological – technocratic – control is sweeping the West can be seen in the Los Angeles school system and is planned to be expanded worldwide. Every child is required to have a ‘Covid’-tracking app scanned daily before they can enter the classroom. The so-called Daily Pass tracking system is produced by Gates’ Microsoft which I’m sure will shock you rigid. The pass will be scanned using a barcode (one step from an inside-the-body barcode) and the information will include health checks, ‘Covid’ tests and vaccinations. Entry codes are for one specific building only and access will only be allowed if a student or teacher has a negative test with a test not testing for the ‘virus’, has no symptoms of anything alleged to be related to ‘Covid’ (symptoms from a range of other illness), and has a temperature under 100 degrees. No barcode, no entry, is planned to be the case for everywhere and not only schools.

Kids are being psychologically prepared to accept this as ‘normal’ their whole life which is why what they can impose in schools is so important to the Cult and its gofers. Long-time American freedom campaigner John Whitehead of the Rutherford Institute was not exaggerating when he said: ‘Databit by databit, we are building our own electronic concentration camps.’ Canada under its Cult gofer prime minister Justin Trudeau has taken a major step towards the real thing with people interned against their will if they test positive with a test not testing for the ‘virus’ when they arrive at a Canadian

airport. They are jailed in internment hotels often without food or water for long periods and with many doors failing to lock there have been sexual assaults. The interned are being charged sometimes $2,000 for the privilege of being abused in this way. Trudeau is fully on board with the Cult and says the 'Covid pandemic' has provided an opportunity for a global 'reset' to permanently change Western civilisation. His number two, Deputy Prime Minister Chrystia Freeland, is a trustee of the World Economic Forum and a Rhodes Scholar. The Trudeau family have long been servants of the Cult. See *The Biggest Secret* and Cathy O'Brien's book *Trance-Formation of America* for the horrific background to Trudeau's father Pierre Trudeau another Canadian prime minister. Hide your fascism behind the façade of a heart-on-the-sleeve liberal. It's a well-honed Cult technique.

What can the 'vaccine' *really* do?

We have a 'virus' never shown to exist and 'variants' of the 'virus' that have also never been shown to exist except, like the 'original', as computer-generated fictions. Even if you believe there's a 'virus' the 'case' to 'death' rate is in the region of 0.23 to 0.15 percent and those 'deaths' are concentrated among the very old around the same average age that people die anyway. In response to this lack of threat (in truth none) psychopaths and idiots, knowingly and unknowingly answering to Gates and the Cult, are seeking to 'vaccinate' every man, woman and child on Planet Earth. Clearly the 'vaccine' is not about 'Covid' – none of this ever has been. So what is it all about *really*? Why the desperation to infuse genetically-manipulating synthetic material into everyone through mRNA fraudulent 'vaccines' with the intent of doing this over and over with the excuses of 'variants' and other 'virus' inventions? Dr Sherri Tenpenny, an osteopathic medical doctor in the United States, has made herself an expert on vaccines and their effects as a vehement campaigner against their use. Tenpenny was board certified in emergency medicine, the director of a level two trauma centre for 12 years, and moved to Cleveland in 1996 to start an integrative

medicine practice which has treated patients from all 50 states and some 17 other countries. Weaning people off pharmaceutical drugs is a speciality.

She became interested in the consequences of vaccines after attending a meeting at the National Vaccine Information Center in Washington DC in 2000 where she 'sat through four days of listening to medical doctors and scientists and lawyers and parents of vaccine injured kids' and asked: 'What's going on?' She had never been vaccinated and never got ill while her father was given a list of vaccines to be in the military and was 'sick his entire life'. The experience added to her questions and she began to examine vaccine documents from the Centers for Disease Control (CDC). After reading the first one, the 1998 version of *The General Recommendations of Vaccination*, she thought: 'This is it?' The document was poorly written and bad science and Tenpenny began 20 years of research into vaccines that continues to this day. She began her research into 'Covid vaccines' in March, 2020, and she describes them as 'deadly'. For many, as we have seen, they already have been. Tenpenny said that in the first 30 days of the 'vaccine' rollout in the United States there had been more than 40,000 adverse events reported to the vaccine adverse event database. A document had been delivered to her the day before that was 172 pages long. 'We have over 40,000 adverse events; we have over 3,100 cases of [potentially deadly] anaphylactic shock; we have over 5,000 neurological reactions.' Effects ranged from headaches to numbness, dizziness and vertigo, to losing feeling in hands or feet and paraesthesia which is when limbs 'fall asleep' and people have the sensation of insects crawling underneath their skin. All this happened in the first 30 days and remember that only about *ten percent* (or far less) of adverse reactions and vaccine-related deaths are estimated to be officially reported. Tenpenny said:

> So can you think of one single product in any industry, any industry, for as long as products have been made on the planet that within 30 days we have 40,000 people complaining of side effects that not only is still on the market but … we've got paid actors telling us how great

they are for getting their vaccine. We're offering people $500 if they will just get their vaccine and we've got nurses and doctors going; 'I got the vaccine, I got the vaccine'.

Tenpenny said they were not going to be 'happy dancing folks' when they began to suffer Bell's palsy (facial paralysis), neuropathies, cardiac arrhythmias and autoimmune reactions that kill through a blood disorder. 'They're not going to be so happy, happy then, but we're never going to see pictures of those people' she said. Tenpenny described the 'vaccine' as 'a well-designed killing tool'.

No off-switch

Bad as the initial consequences had been Tenpenny said it would be maybe 14 months before we began to see the 'full ravage' of what is going to happen to the 'Covid vaccinated' with full-out consequences taking anything between two years and 20 years to show. You can understand why when you consider that variations of the 'Covid vaccine' use mRNA (messenger RNA) to in theory activate the immune system to produce protective antibodies without using the actual 'virus'. How can they when it's a computer program and they've never isolated what they claim is the 'real thing'? Instead they use *synthetic* mRNA. They are inoculating synthetic material into the body which through a technique known as the Trojan horse is absorbed into cells to change the nature of DNA. Human DNA is changed by an infusion of messenger RNA and with each new 'vaccine' of this type it is changed even more. Say so and you are banned by Cult Internet platforms. The contempt the contemptuous Mark Zuckerberg has for the truth and human health can be seen in an internal Facebook video leaked to the Project Veritas investigative team in which he said of the 'Covid vaccines': '… I share some caution on this because we just don't know the long term side-effects of basically modifying people's DNA and RNA.' At the same time this disgusting man's Facebook was censoring and banning anyone saying exactly the same. He must go before a Nuremberg trial for crimes against humanity when he *knows* that he

is censoring legitimate concerns and denying the right of informed consent on behalf of the Cult that owns him. People have been killed and damaged by the very 'vaccination' technique he cast doubt on himself when they may not have had the 'vaccine' with access to information that he denied them. The plan is to have at least annual 'Covid vaccinations', add others to deal with invented 'variants', and change all other vaccines into the mRNA system. Pfizer executives told shareholders at a virtual Barclays Global Healthcare Conference in March, 2021, that the public may need a third dose of 'Covid vaccine', plus regular yearly boosters and the company planned to hike prices to milk the profits in a 'significant opportunity for our vaccine'. These are the professional liars, cheats and opportunists who are telling you their 'vaccine' is safe. Given this volume of mRNA planned to be infused into the human body and its ability to then replicate we will have a transformation of human genetics from biological to synthetic biological – exactly the long-time Cult plan for reasons we'll see – and many will die. Sherri Tenpenny said of this replication:

> It's like having an on-button but no off-button and that whole mechanism … they actually give it a name and they call it the Trojan horse mechanism, because it allows that [synthetic] virus and that piece of that [synthetic] virus to get inside of your cells, start to replicate and even get inserted into other parts of your DNA as a Trojan-horse.

Ask the overwhelming majority of people who have the 'vaccine' what they know about the contents and what they do and they would reply: 'The government says it will stop me getting the virus.' Governments give that false impression on purpose to increase take-up. You can read Sherri Tenpenny's detailed analysis of the health consequences in her blog at Vaxxter.com, but in summary these are some of them. She highlights the statement by Bill Gates about how human beings can become their own 'vaccine manufacturing machine'. The man is insane. ['Vaccine'-generated] 'antibodies' carry synthetic messenger RNA into the cells and the damage starts, Tenpenny contends, and she says that lungs can be adversely affected through varying degrees of pus and bleeding which

obviously affects breathing and would be dubbed 'Covid-19'. Even more sinister was the impact of 'antibodies' on macrophages, a white blood cell of the immune system. They consist of Type 1 and Type 2 which have very different functions. She said Type 1 are 'hyper-vigilant' white blood cells which 'gobble up' bacteria etc. However, in doing so, this could cause inflammation and in extreme circumstances be fatal. She says these affects are mitigated by Type 2 macrophages which kick in to calm down the system and stop it going rogue. They clear up dead tissue debris and reduce inflammation that the Type 1 'fire crews' have caused. Type 1 kills the infection and Type 2 heals the damage, she says. This is her punchline with regard to 'Covid vaccinations': She says that mRNA 'antibodies' block Type 2 macrophages by attaching to them and deactivating them. This meant that when the Type 1 response was triggered by infection there was nothing to stop that getting out of hand by calming everything down. There's an on-switch, but no off-switch, she says. What follows can be 'over and out, see you when I see you'.

Genetic suicide

Tenpenny also highlights the potential for autoimmune disease – the body attacking itself – which has been associated with vaccines since they first appeared. Infusing a synthetic foreign substance into cells could cause the immune system to react in a panic believing that the body is being overwhelmed by an invader (it is) and the consequences can again be fatal. There is an autoimmune response known as a 'cytokine storm' which I have likened to a homeowner panicked by an intruder and picking up a gun to shoot randomly in all directions before turning the fire on himself. The immune system unleashes a storm of inflammatory response called cytokines to a threat and the body commits hara-kiri. The lesson is that you mess with the body's immune response at your peril and these 'vaccines' seriously – fundamentally – mess with immune response. Tenpenny refers to a consequence called anaphylactic shock which is a severe and highly dangerous allergic reaction when the immune system

floods the body with chemicals. She gives the example of having a bee sting which primes the immune system and makes it sensitive to those chemicals. When people are stung again maybe years later the immune response can be so powerful that it leads to anaphylactic shock. Tenpenny relates this 'shock' with regard to the 'Covid vaccine' to something called polyethylene glycol or PEG. Enormous numbers of people have become sensitive to this over decades of use in a whole range of products and processes including food, drink, skin creams and 'medicine'. Studies have claimed that some 72 percent of people have antibodies triggered by PEG compared with two percent in the 1960s and allergic hypersensitive reactions to this become a gathering cause for concern. Tenpenny points out that the 'mRNA vaccine' is coated in a 'bubble' of polyethylene glycol which has the potential to cause anaphylactic shock through immune sensitivity. Many reports have appeared of people reacting this way after having the 'Covid vaccine'. What do we think is going to happen as humanity has more and more of these 'vaccines'? Tenpenny said: 'All these pictures we have seen with people with these rashes … these weepy rashes, big reactions on their arms and things like that – it's an acute allergic reaction most likely to the polyethylene glycol that you've been previously primed and sensitised to.'

Those who have not studied the conspiracy and its perpetrators at length might think that making the population sensitive to PEG and then putting it in these 'vaccines' is just a coincidence. It is not. It is instead testament to how carefully and coldly-planned current events have been and the scale of the conspiracy we are dealing with. Tenpenny further explains that the 'vaccine' mRNA procedure can breach the blood-brain barrier which protects the brain from toxins and other crap that will cause malfunction. In this case they could make two proteins corrupt brain function to cause Amyotrophic lateral sclerosis (ALS) , a progressive nervous system disease leading to loss of muscle control, and frontal lobe degeneration – Alzheimer's and dementia. Immunologist J. Bart Classon published a paper connecting mRNA 'vaccines' to prion

disease which can lead to Alzheimer's and other forms of neurogenerative disease while others have pointed out the potential to affect the placenta in ways that make women infertile. This will become highly significant in the next chapter when I will discuss other aspects of this non-vaccine that relate to its nanotechnology and transmission from the injected to the uninjected.

Qualified in idiocy

Tenpenny describes how research has confirmed that these 'vaccine'-generated antibodies can interact with a range of other tissues in the body and attack many other organs including the lungs. 'This means that if you have a hundred people standing in front of you that all got this shot they could have a hundred different symptoms.' Anyone really think that Cult gofers like the Queen, Tony Blair, Christopher Whitty, Anthony Fauci, and all the other psychopaths have really had this 'vaccine' in the pictures we've seen? Not a bloody chance. Why don't doctors all tell us about all these dangers and consequences of the 'Covid vaccine'? Why instead do they encourage and pressure patients to have the shot? Don't let's think for a moment that doctors and medical staff can't be stupid, lazy, and psychopathic and that's without the financial incentives to give the jab. Tenpenny again:

> Some people are going to die from the vaccine directly but a large number of people are going to start to get horribly sick and get all kinds of autoimmune diseases 42 days to maybe a year out. What are they going to do, these stupid doctors who say; 'Good for you for getting that vaccine.' What are they going to say; 'Oh, it must be a mutant, we need to give an extra dose of that vaccine.'
>
> Because now the vaccine, instead of one dose or two doses we need three or four because the stupid physicians aren't taking the time to learn anything about it. If I can learn this sitting in my living room reading a 19 page paper and several others so can they. There's nothing special about me, I just take the time to do it.

Remember how Sara Kayat, the NHS and TV doctor, said that the 'Covid vaccine' would '100 percent prevent hospitalisation and death'. Doctors can be idiots like every other profession and they

should not be worshipped as infallible. They are not and far from it. Behind many medical and scientific 'experts' lies an uninformed prat trying to hide themselves from you although in the 'Covid' era many have failed to do so as with UK narrative-repeating 'TV doctor' Hilary Jones. Pushing back against the minority of proper doctors and scientists speaking out against the 'vaccine' has been the entire edifice of the Cult global state in the form of governments, medical systems, corporations, mainstream media, Silicon Valley, and an army of compliant doctors, medical staff and scientists willing to say anything for money and to enhance their careers by promoting the party line. If you do that you are an 'expert' and if you won't you are an 'anti-vaxxer' and 'Covidiot'. The pressure to be 'vaccinated' is incessant. We have even had reports claiming that the 'vaccine' can help cure cancer and Alzheimer's and make the lame walk. I am waiting for the announcement that it can bring you coffee in the morning and cook your tea. Just as the symptoms of 'Covid' seem to increase by the week so have the miracles of the 'vaccine'. American supermarket giant Kroger Co. offered nearly 500,000 employees in 35 states a $100 bonus for having the 'vaccine' while donut chain Krispy Kreme promised 'vaccinated' customers a free glazed donut every day for the rest of 2021. Have your DNA changed and you will get a doughnut although we might not have to give you them for long. Such offers and incentives confirm the desperation.

Perhaps the worse vaccine-stunt of them all was UK 'Health' Secretary Matt-the-prat Hancock on live TV after watching a clip of someone being 'vaccinated' when the roll-out began. Hancock faked tears so badly it was embarrassing. Brain-of-Britain Piers Morgan, the lockdown-supporting, 'vaccine' supporting, 'vaccine' passport-supporting, TV host played along with Hancock – 'You're quite emotional about that' he said in response to acting so atrocious it would have been called out at a school nativity which will presumably today include Mary and Jesus in masks, wise men keeping their camels six feet apart, and shepherds under tent arrest. System-serving Morgan tweeted this: 'Love the idea of covid vaccine passports for everywhere: flights, restaurants, clubs, football, gyms,

shops etc. It's time covid-denying, anti-vaxxer loonies had their bullsh*t bluff called & bar themselves from going anywhere that responsible citizens go.' If only I could aspire to his genius. To think that Morgan, who specialises in shouting over anyone he disagrees with, was lauded as a free speech hero when he lost his job after storming off the set of his live show like a child throwing his dolly out of the pram. If he is a free speech hero we are in real trouble. I have no idea what 'bullsh*t' means, by the way, the * throws me completely.

The Cult is desperate to infuse its synthetic DNA-changing concoction into everyone and has been using every lie, trick and intimidation to do so. The question of '*Why*?' we shall now address.

CHAPTER TEN

Human 2.0

I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted –
Alan Turing (1912-1954), the 'Father of artificial intelligence'

I have been exposing for decades the plan to transform the human body from a biological to a synthetic-biological state. The new human that I will call Human 2.0 is planned to be connected to artificial intelligence and a global AI 'Smart Grid' that would operate as one global system in which AI would control everything from your fridge to your heating system to your car to your mind. Humans would no longer be 'human', but post-human and sub-human, with their thinking and emotional processes replaced by AI.

What I said sounded crazy and beyond science fiction and I could understand that. To any balanced, rational, mind it *is* crazy. Today, however, that world is becoming reality and it puts the 'Covid vaccine' into its true context. Ray Kurzweil is the ultra-Zionist 'computer scientist, inventor and futurist' and co-founder of the Singularity University. Singularity refers to the merging of humans with machines or 'transhumanism'. Kurzweil has said humanity would be connected to the cyber 'cloud' in the period of the ever-recurring year of 2030:

Our thinking … will be a hybrid of biological and non-biological thinking … humans will be able to extend their limitations and 'think in the cloud' … We're going to put gateways to the

cloud in our brains ... We're going to gradually merge and enhance ourselves ... In my view, that's the nature of being human – we transcend our limitations. As the technology becomes vastly superior to what we are then the small proportion that is still human gets smaller and smaller and smaller until it's just utterly negligible.

They are trying to sell this end-of-humanity-as-we-know-it as the next stage of 'evolution' when we become super-human and 'like the gods'. They are lying to you. Shocked, eh? The population, and again especially the young, have been manipulated into addiction to technologies designed to enslave them for life. First they induced an addiction to smartphones (holdables); next they moved to technology on the body (wearables); and then began the invasion of the body (implantables). I warned way back about the plan for microchipped people and we are now entering that era. We should not be diverted into thinking that this refers only to chips we can see. Most important are the nanochips known as smart dust, neural dust and nanobots which are far too small to be seen by the human eye. Nanotechnology is everywhere, increasingly in food products, and released into the atmosphere by the geoengineering of the skies funded by Bill Gates to 'shut out the Sun' and 'save the planet from global warming'. Gates has been funding a project to spray millions of tonnes of chalk (calcium carbonate) into the stratosphere over Sweden to 'dim the Sun' and cool the Earth. Scientists warned the move could be disastrous for weather systems in ways no one can predict and opposition led to the Swedish space agency announcing that the 'experiment' would not be happening as planned in the summer of 2021; but it shows where the Cult is going with dimming the impact of the Sun and there's an associated plan to change the planet's atmosphere. Who gives psychopath Gates the right to dictate to the entire human race and dismantle planetary systems? The world will not be safe while this man is at large.

The global warming hoax has made the Sun, like the gas of life, something to fear when both are essential to good health and human survival (more inversion). The body transforms sunlight into vital vitamin D through a process involving … *cholesterol*. This is the cholesterol we are also told to fear. We are urged to take Big Pharma

statin drugs to reduce cholesterol and it's all systematic. Reducing cholesterol means reducing vitamin D uptake with all the multiple health problems that will cause. At least if you take statins long term it saves the government from having to pay you a pension. The delivery system to block sunlight is widely referred to as chemtrails although these have a much deeper agenda, too. They appear at first to be contrails or condensation trails streaming from aircraft into cold air at high altitudes. Contrails disperse very quickly while chemtrails do not and spread out across the sky before eventually their content falls to earth. Many times I have watched aircraft cross-cross a clear blue sky releasing chemtrails until it looks like a cloudy day. Chemtrails contain many things harmful to humans and the natural world including toxic heavy metals, aluminium (see Alzheimer's) and nanotechnology. Ray Kurzweil reveals the reason without actually saying so: 'Nanobots will infuse all the matter around us with information. Rocks, trees, everything will become these intelligent creatures.' How do you deliver that? *From the sky*. Self-replicating nanobots would connect everything to the Smart Grid. The phenomenon of Morgellons disease began in the chemtrail era and the correlation has led to it being dubbed the 'chemtrail disease'. Self-replicating fibres appear in the body that can be pulled out through the skin. Morgellons fibres continue to grow outside the body and have a form of artificial intelligence. I cover this at greater length in *Phantom Self*.

'Vaccine' operating system

'Covid vaccines' with their self-replicating synthetic material are also designed to make the connection between humanity and Kurzweil's 'cloud'. American doctor and dedicated campaigner for truth, Carrie Madej, an Internal Medicine Specialist in Georgia with more than 20 years medical experience, has highlighted the nanotechnology aspect of the fake 'vaccines'. She explains how one of the components in at least the Moderna and Pfizer synthetic potions are 'lipid nanoparticles' which are 'like little tiny computer bits' – a 'sci-fi substance' known as nanobots and hydrogel which can be 'triggered

at any moment to deliver its payload' and act as 'biosensors'. The synthetic substance had 'the ability to accumulate data from your body like your breathing, your respiration, thoughts and emotions, all kind of things' and each syringe could carry a *million* nanobots:

This substance because it's like little bits of computers in your body, crazy, but it's true, it can do that, [and] obviously has the ability to act through Wi-Fi. It can receive and transmit energy, messages, frequencies or impulses. That issue has never been addressed by these companies. What does that do to the human?

Just imagine getting this substance in you and it can react to things all around you, the 5G, your smart device, your phones, what is happening with that? What if something is triggering it, too, like an impulse, a frequency? We have something completely foreign in the human body.

Madej said her research revealed that electromagnetic (EMF) frequencies emitted by phones and other devices had increased dramatically in the same period of the 'vaccine' rollout and she was seeing more people with radiation problems as 5G and other electromagnetic technology was expanded and introduced to schools and hospitals. She said she was 'floored with the EMF coming off' the devices she checked. All this makes total sense and syncs with my own work of decades when you think that Moderna refers in documents to its mRNA 'vaccine' as an 'operating system':

Recognizing the broad potential of mRNA science, we set out to create an mRNA technology platform that functions very much like an operating system on a computer. It is designed so that it can plug and play interchangeably with different programs. In our case, the 'program' or 'app' is our mRNA drug – the unique mRNA sequence that codes for a protein …

… Our MRNA Medicines – 'The 'Software Of Life': When we have a concept for a new mRNA medicine and begin research, fundamental components are already in place. Generally, the only thing that changes from one potential mRNA medicine to another is the coding region – the actual genetic code that instructs ribosomes to make protein. Utilizing these instruction sets gives our investigational mRNA medicines a software-like quality. We also have the ability to combine different mRNA sequences encoding for different proteins in a single mRNA investigational medicine.

Who needs a real 'virus' when you can create a computer version to justify infusing your operating system into the entire human race on the road to making living, breathing people into cyborgs? What is missed with the 'vaccines' is the *digital* connection between synthetic material and the body that I highlighted earlier with the study that hacked a computer with human DNA. On one level the body is digital, based on mathematical codes, and I'll have more about that in the next chapter. Those who ridiculously claim that mRNA 'vaccines' are not designed to change human genetics should explain the words of Dr Tal Zaks, chief medical officer at Moderna, in a 2017 TED talk. He said that over the last 30 years 'we've been living this phenomenal digital scientific revolution, and I'm here today to tell you, that we are actually *hacking the software of life*, and that it's changing the way we think about prevention and treatment of disease':

In every cell there's this thing called messenger RNA, or mRNA for short, that transmits the critical information from the DNA in our genes to the protein, which is really the stuff we're all made out of. This is the critical information that determines what the cell will do. So we think about it as an operating system. So if you could change that, if you could introduce a line of code, or change a line of code, it turns out, that has profound implications for everything, from the flu to cancer.

Zaks should more accurately have said that this has profound implications for the human genetic code and the nature of DNA. Communications within the body go both ways and not only one. But, hey, no, the 'Covid vaccine' will not affect your genetics. Cult fact-checkers say so even though the man who helped to develop the mRNA technique says that it does. Zaks said in 2017:

If you think about what it is we're trying to do. We've taken information and our understanding of that information and how that information is transmitted in a cell, and we've taken our understanding of medicine and how to make drugs, and we're fusing the two. We think of it as information therapy.

I have been writing for decades that the body is an information field communicating with itself and the wider world. This is why

radiation which is information can change the information field of body and mind through phenomena like 5G and change their nature and function. 'Information therapy' means to change the body's information field and change the way it operates. DNA is a receiver-transmitter of information and can be mutated by information like mRNA synthetic messaging. Technology to do this has been ready and waiting in the underground bases and other secret projects to be rolled out when the 'Covid' hoax was played. 'Trials' of such short and irrelevant duration were only for public consumption. When they say the 'vaccine' is 'experimental' that is not true. It may appear to be 'experimental' to those who don't know what's going on, but the trials have already been done to ensure the Cult gets the result it desires. Zaks said that it took decades to sequence the human genome, completed in 2003, but now they could do it in a week. By 'they' he means scientists operating in the public domain. In the secret projects they were sequencing the genome in a week long before even 2003.

Deluge of mRNA

Highly significantly the Moderna document says the guiding premise is that if using mRNA as a medicine works for one disease then it should work for many diseases. They were leveraging the flexibility afforded by their platform and the fundamental role mRNA plays in protein synthesis to pursue mRNA medicines for a broad spectrum of diseases. Moderna is confirming what I was saying through 2020 that multiple 'vaccines' were planned for 'Covid' (and later invented 'variants') and that previous vaccines would be converted to the mRNA system to infuse the body with massive amounts of genetically-manipulating synthetic material to secure a transformation to a synthetic-biological state. The 'vaccines' are designed to kill stunning numbers as part of the long-exposed Cult depopulation agenda and transform the rest. Given this is the goal you can appreciate why there is such hysterical demand for every human to be 'vaccinated' for an alleged 'disease' that has an estimated 'infection' to 'death' ratio of 0.23-0.15 percent. As I write

children are being given the 'vaccine' in trials (their parents are a disgrace) and ever-younger people are being offered the vaccine for a 'virus' that even if you believe it exists has virtually zero chance of harming them. Horrific effects of the 'trials' on a 12-year-old girl were revealed by a family member to be serious brain and gastric problems that included a bowel obstruction and the inability to swallow liquids or solids. She was unable to eat or drink without throwing up, had extreme pain in her back, neck and abdomen, and was paralysed from the waist down which stopped her urinating unaided. When the girl was first taken to hospital doctors said it was all in her mind. She was signed up for the 'trial' by her parents for whom no words suffice. None of this 'Covid vaccine' insanity makes any sense unless you see what the 'vaccine' really is – a body-changer. Synthetic biology or 'SynBio' is a fast-emerging and expanding scientific discipline which includes everything from genetic and molecular engineering to electrical and computer engineering. Synthetic biology is defined in these ways:

- A multidisciplinary area of research that seeks to create new biological parts, devices, and systems, or to redesign systems that are already found in nature.

- The use of a mixture of physical engineering and genetic engineering to create new (and therefore synthetic) life forms.

- An emerging field of research that aims to combine the knowledge and methods of biology, engineering and related disciplines in the design of chemically-synthesized DNA to create organisms with novel or enhanced characteristics and traits (synthetic organisms including humans).

We now have synthetic blood, skin, organs and limbs being developed along with synthetic body parts produced by 3D printers. These are all elements of the synthetic human programme and this comment by Kurzweil's co-founder of the Singularity University,

Peter Diamandis, can be seen in a whole new light with the 'Covid' hoax and the sanctions against those that refuse the 'vaccine':

Anybody who is going to be resisting the progress forward [to transhumanism] is going to be resisting evolution and, fundamentally, they will die out. It's not a matter of whether it's good or bad. It's going to happen.

'Resisting evolution'? What absolute bollocks. The arrogance of these people is without limit. His 'it's going to happen' mantra is another way of saying 'resistance is futile' to break the spirit of those pushing back and we must not fall for it. Getting this genetically-transforming 'vaccine' into everyone is crucial to the Cult plan for total control and the desperation to achieve that is clear for anyone to see. Vaccine passports are a major factor in this and they, too, are a form of resistance is futile. It's NOT. The paper funded by the Rockefeller Foundation for the 2013 'health conference' in China said:

We will interact more with artificial intelligence. The use of robotics, bio-engineering to augment human functioning is already well underway and will advance. Re-engineering of humans into potentially separate and unequal forms through genetic engineering or mixed human-robots raises debates on ethics and equality.

A new demography is projected to emerge after 2030 [that year again] of technologies (robotics, genetic engineering, nanotechnology) producing robots, engineered organisms, 'nanobots' and artificial intelligence (AI) that can self-replicate. Debates will grow on the implications of an impending reality of human designed life.

What is happening today is so long planned. The world army enforcing the will of the world government is intended to be a robot army, not a human one. Today's military and its technologically 'enhanced' troops, pilotless planes and driverless vehicles are just stepping stones to that end. Human soldiers are used as Cult fodder and its time they woke up to that and worked for the freedom of the population instead of their own destruction and their family's destruction – the same with the police. Join us and let's sort this out. The phenomenon of enforce my own destruction is widespread in the 'Covid' era with Woker 'luvvies' in the acting and entertainment

industries supporting 'Covid' rules which have destroyed their profession and the same with those among the public who put signs on the doors of their businesses 'closed due to Covid – stay safe' when many will never reopen. It's a form of masochism and most certainly insanity.

Transgender = transhumanism

When something explodes out of nowhere and is suddenly everywhere it is always the Cult agenda and so it is with the tidal wave of claims and demands that have infiltrated every aspect of society under the heading of 'transgenderism'. The term 'trans' is so 'in' and this is the dictionary definition:

A prefix meaning 'across', 'through', occurring … in loanwords from Latin, used in particular for denoting movement or conveyance from place to place (transfer; transmit; transplant) or complete change (transform; transmute), or to form adjectives meaning 'crossing', 'on the other side of', or 'going beyond' the place named (transmontane; transnational; trans-Siberian).

Transgender means to go beyond gender and transhuman means to go beyond human. Both are aspects of the Cult plan to transform the human body to a synthetic state with *no gender*. Human 2.0 is not designed to procreate and would be produced technologically with no need for parents. The new human would mean the end of parents and so men, and increasingly women, are being targeted for the deletion of their rights and status. Parental rights are disappearing at an ever-quickening speed for the same reason. The new human would have no need for men or women when there is no procreation and no gender. Perhaps the transgender movement that appears to be in a permanent state of frenzy might now contemplate on how it is being used. This was never about transgender rights which are only the interim excuse for confusing gender, particularly in the young, on the road to *fusing* gender. Transgender activism is not an end; it is a *means* to an end. We see again the technique of creative destruction in which you destroy the status quo to 'build back better' in the form that you want. The gender status quo had to be

destroyed by persuading the Cult-created Woke mentality to believe that you can have 100 genders or more. A programme for 9 to 12 year olds produced by the Cult-owned BBC promoted the 100 genders narrative. The very idea may be the most monumental nonsense, but it is not what is true that counts, only what you can make people *believe* is true. Once the gender of 2 + 2 = 4 has been dismantled through indoctrination, intimidation and 2 + 2 = 5 then the new no-gender normal can take its place with Human 2.0. Aldous Huxley revealed the plan in his prophetic *Brave New World* in 1932:

> Natural reproduction has been done away with and children are created, decanted', and raised in 'hatcheries and conditioning centres'. From birth, people are genetically designed to fit into one of five castes, which are further split into 'Plus' and 'Minus' members and designed to fulfil predetermined positions within the social and economic strata of the World State.

How could Huxley know this in 1932? For the same reason George Orwell knew about the Big Brother state in 1948, Cult insiders I have quoted knew about it in 1969, and I have known about it since the early 1990s. If you are connected to the Cult or you work your balls off to uncover the plan you can predict the future. The process is simple. If there is a plan for the world and nothing intervenes to stop it then it will happen. Thus if you communicate the plan ahead of time you are perceived to have predicted the future, but you haven't. You have revealed the plan which without intervention will become the human future. The whole reason I have done what I have is to alert enough people to inspire an intervention and maybe at last that time has come with the Cult and its intentions now so obvious to anyone with a brain in working order.

The future is here

Technological wombs that Huxley described to replace parent procreation are already being developed and they are only the projects we know about in the public arena. Israeli scientists told *The Times of Israel* in March, 2021, that they have grown 250-cell embryos

into mouse foetuses with fully formed organs using artificial wombs in a development they say could pave the way for gestating humans outside the womb. Professor Jacob Hanna of the Weizmann Institute of Science said:

We took mouse embryos from the mother at day five of development, when they are just of 250 cells, and had them in the incubator from day five until day 11, by which point they had grown all their organs.

By day 11 they make their own blood and have a beating heart, a fully developed brain. Anybody would look at them and say, 'this is clearly a mouse foetus with all the characteristics of a mouse.' It's gone from being a ball of cells to being an advanced foetus.

A special liquid is used to nourish embryo cells in a laboratory dish and they float on the liquid to duplicate the first stage of embryonic development. The incubator creates all the right conditions for its development, Hanna said. The liquid gives the embryo 'all the nutrients, hormones and sugars they need' along with a custom-made electronic incubator which controls gas concentration, pressure and temperature. The cutting-edge in the underground bases and other secret locations will be light years ahead of that, however, and this was reported by the London *Guardian* in 2017:

We are approaching a biotechnological breakthrough. Ectogenesis, the invention of a complete external womb, could completely change the nature of human reproduction. In April this year, researchers at the Children's Hospital of Philadelphia announced their development of an artificial womb.

The article was headed 'Artificial wombs could soon be a reality. What will this mean for women?' What would it mean for children is an even bigger question. No mother to bond with only a machine in preparation for a life of soulless interaction and control in a world governed by machines (see the *Matrix* movies). Now observe the calculated manipulations of the 'Covid' hoax as human interaction and warmth has been curtailed by distancing, isolation and fear with people communicating via machines on a scale never seen before.

These are all dots in the same picture as are all the personal assistants, gadgets and children's toys through which kids and adults communicate with AI as if it is human. The AI 'voice' on Sat-Nav should be included. All these things are psychological preparation for the Cult endgame. Before you can make a physical connection with AI you have to make a psychological connection and that is what people are being conditioned to do with this ever gathering human-AI interaction. Movies and TV programmes depicting the transhuman, robot dystopia relate to a phenomenon known as 'pre-emptive programming' in which the world that is planned is portrayed everywhere in movies, TV and advertising. This is conditioning the conscious and subconscious mind to become familiar with the planned reality to dilute resistance when it happens for real. What would have been a shock such is the change is made less so. We have young children put on the road to transgender transition surgery with puberty blocking drugs at an age when they could never be able to make those life-changing decisions.

Rachel Levine, a professor of paediatrics and psychiatry who believes in treating children this way, became America's highest-ranked openly-transgender official when she was confirmed as US Assistant Secretary at the Department of Health and Human Services after being nominated by Joe Biden (the Cult). Activists and governments press for laws to deny parents a say in their children's transition process so the kids can be isolated and manipulated into agreeing to irreversible medical procedures. A Canadian father Robert Hoogland was denied bail by the Vancouver Supreme Court in 2021 and remained in jail for breaching a court order that he stay silent over his young teenage daughter, a minor, who was being offered life-changing hormone therapy without parental consent. At the age of 12 the girl's 'school counsellor' said she may be transgender, referred her to a doctor and told the school to treat her like a boy. This is another example of state-serving schools imposing ever more control over children's lives while parents have ever less.

Contemptible and extreme child abuse is happening all over the world as the Cult gender-fusion operation goes into warp-speed.

Why the war on men – and now women?

The question about what artificial wombs mean for women should rightly be asked. The answer can be seen in the deletion of women's rights involving sport, changing rooms, toilets and status in favour of people in male bodies claiming to identify as women. I can identify as a mountain climber, but it doesn't mean I can climb a mountain any more than a biological man can be a biological woman. To believe so is a triumph of belief over factual reality which is the very perceptual basis of everything Woke. Women's sport is being destroyed by allowing those with male bodies who say they identify as female to 'compete' with girls and women. Male body 'women' dominate 'women's' competition with their greater muscle mass, bone density, strength and speed. With that disadvantage sport for women loses all meaning. To put this in perspective nearly 300 American high school boys can run faster than the quickest woman sprinter in the world. Women are seeing their previously protected spaces invaded by male bodies simply because they claim to identify as women. That's all they need to do to access all women's spaces and activities under the Biden 'Equality Act' that destroys equality for women with the usual Orwellian Woke inversion. Male sex offenders have already committed rapes in women's prisons after claiming to identify as women to get them transferred. Does this not matter to the Woke 'equality' hypocrites? Not in the least. What matters to Cult manipulators and funders behind transgender activists is to advance gender fusion on the way to the no-gender 'human'. When you are seeking to impose transparent nonsense like this, or the 'Covid' hoax, the only way the nonsense can prevail is through censorship and intimidation of dissenters, deletion of factual information, and programming of the unquestioning, bewildered and naive. You don't have to scan the world for long to see that all these things are happening.

Many women's rights organisations have realised that rights and status which took such a long time to secure are being eroded and that it is systematic. Kara Dansky of the global Women's Human Rights Campaign said that Biden's transgender executive order immediately he took office, subsequent orders, and Equality Act legislation that followed 'seek to erase women and girls in the law as a category'. *Exactly*. I said during the long ago-started war on men (in which many women play a crucial part) that this was going to turn into a war on them. The Cult is phasing out *both* male and female genders. To get away with that they are brought into conflict so they are busy fighting each other while the Cult completes the job with no unity of response. Unity, people, *unity*. We need unity everywhere. Transgender is the only show in town as the big step towards the no-gender human. It's not about rights for transgender people and never has been. Woke political correctness is deleting words relating to genders to the same end. Wokers believe this is to be 'inclusive' when the opposite is true. They are deleting words describing gender because gender *itself* is being deleted by Human 2.0. Terms like 'man', 'woman', 'mother' and 'father' are being deleted in the universities and other institutions to be replaced by the *no*-gender, not trans-gender, 'individuals' and 'guardians'. Women's rights campaigner Maria Keffler of Partners for Ethical Care said: 'Children are being taught from kindergarten upward that some boys have a vagina, some girls have a penis, and that kids can be any gender they want to be.' Do we really believe that suddenly countries all over the world at the same time had the idea of having drag queens go into schools or read transgender stories to very young children in the local library? It's coldly-calculated confusion of gender on the way to the fusion of gender. Suzanne Vierling, a psychologist from Southern California, made another important point:

Yesterday's slave woman who endured gynecological medical experiments is today's girl-child being butchered in a booming gender-transitioning sector. Ovaries removed, pushing her into menopause and osteoporosis, uncharted territory, and parents' rights and authority decimated.

The erosion of parental rights is a common theme in line with the Cult plans to erase the very concept of parents and 'ovaries removed, pushing her into menopause' means what? Those born female lose the ability to have children – another way to discontinue humanity as we know it.

Eliminating Human 1.0 (before our very eyes)

To pave the way for Human 2.0 you must phase out Human 1.0. This is happening through plummeting sperm counts and making women infertile through an onslaught of chemicals, radiation (including smartphones in pockets of men) and mRNA 'vaccines'. Common agriculture pesticides are also having a devastating impact on human fertility. I have been tracking collapsing sperm counts in the books for a long time and in 2021 came a book by fertility scientist and reproductive epidemiologist Shanna Swan, *Count Down: How Our Modern World Is Threatening Sperm Counts, Altering Male and Female Reproductive Development and Imperiling the Future of the Human Race*. She reports how the global fertility rate dropped by *half* between 1960 and 2016 with America's birth rate 16 percent below where it needs to be to sustain the population. Women are experiencing declining egg quality, more miscarriages, and more couples suffer from infertility. Other findings were an increase in erectile dysfunction, infant boys developing more genital abnormalities, male problems with conception, and plunging levels of the male hormone testosterone which would explain why so many men have lost their backbone and masculinity. This has been very evident during the 'Covid' hoax when women have been prominent among the Pushbackers and big strapping blokes have bowed their heads, covered their faces with a nappy and quietly submitted. Mind control expert Cathy O'Brien also points to how global education introduced the concept of 'we're all winners' in sport and classrooms: 'Competition was defused, and it in turn defused a sense of fighting back.' This is another version of the 'equity' doctrine in which you drive down rather than raise up. What a contrast in Cult-controlled China with its global ambitions

where the government published plans in January, 2021, to 'cultivate masculinity' in boys from kindergarten through to high school in the face of a 'masculinity crisis'. A government adviser said boys would be soon become 'delicate, timid and effeminate' unless action was taken. Don't expect any similar policy in the targeted West. A 2006 study showed that a 65-year-old man in 2002 had testosterone levels *15 percent* lower than a 65-year-old man in 1987 while a 2020 study found a similar story with young adults and adolescents. Men are getting prescriptions for testosterone replacement therapy which causes an even greater drop in sperm count with up to 99 percent seeing sperm counts drop to zero during the treatment. More sperm is defective and malfunctioning with some having two heads or not pursuing an egg.

A class of *synthetic* chemicals known as phthalates are being blamed for the decline. These are found everywhere in plastics, shampoos, cosmetics, furniture, flame retardants, personal care products, pesticides, canned foods and even receipts. Why till receipts? Everyone touches them. Let no one delude themselves that all this is not systematic to advance the long-time agenda for human body transformation. Phthalates mimic hormones and disrupt the hormone balance causing testosterone to fall and genital birth defects in male infants. Animals and fish have been affected in the same way due to phthalates and other toxins in rivers. When fish turn gay or change sex through chemicals in rivers and streams it is a pointer to why there has been such an increase in gay people and the sexually confused. It doesn't matter to me what sexuality people choose to be, but if it's being affected by chemical pollution and consumption then we need to know. Does anyone really think that this is not connected to the transgender agenda, the war on men and the condemnation of male 'toxic masculinity'? You watch this being followed by 'toxic femininity'. It's already happening. When breastfeeding becomes 'chest-feeding', pregnant women become pregnant people along with all the other Woke claptrap you know that the world is going insane and there's a Cult scam in progress. Transgender activists are promoting the Cult agenda while Cult

billionaires support and fund the insanity as they laugh themselves to sleep at the sheer stupidity for which humans must be infamous in galaxies far, far away.

'Covid vaccines' and female infertility

We can now see why the 'vaccine' has been connected to potential infertility in women. Dr Michael Yeadon, former Vice President and Chief Scientific Advisor at Pfizer, and Dr Wolfgang Wodarg in Germany, filed a petition with the European Medicines Agency in December, 2020, urging them to stop trials for the Pfizer/BioNTech shot and all other mRNA trials until further studies had been done. They were particularly concerned about possible effects on fertility with 'vaccine'-produced antibodies attacking the protein Syncytin-1 which is responsible for developing the placenta. The result would be infertility 'of indefinite duration' in women who have the 'vaccine' with the placenta failing to form. Section 10.4.2 of the Pfizer/BioNTech trial protocol says that pregnant women or those who might become so should not have mRNA shots. Section 10.4 warns men taking mRNA shots to 'be abstinent from heterosexual intercourse' and not to donate sperm. The UK government said that it *did not know* if the mRNA procedure had an effect on fertility. *Did not know?* These people have to go to jail. UK government advice did not recommend at the start that pregnant women had the shot and said they should avoid pregnancy for at least two months after 'vaccination'. The 'advice' was later updated to pregnant women should only have the 'vaccine' if the benefits outweighed the risks to mother and foetus. What the hell is that supposed to mean? Then 'spontaneous abortions' began to appear and rapidly increase on the adverse reaction reporting schemes which include only a fraction of adverse reactions. Thousands and ever-growing numbers of 'vaccinated' women are describing changes to their menstrual cycle with heavier blood flow, irregular periods and menstruating again after going through the menopause – all links to reproduction effects. Women are passing blood clots and the lining of their uterus while men report erectile dysfunction and blood effects. Most

significantly of all *un*vaccinated women began to report similar menstrual changes after interaction with *'vaccinated'* people and men and children were also affected with bleeding noses, blood clots and other conditions. 'Shedding' is when vaccinated people can emit the content of a vaccine to affect the unvaccinated, but this is different. 'Vaccinated' people were not shedding a 'live virus' allegedly in 'vaccines' as before because the fake 'Covid vaccines' involve synthetic material and other toxicity. Doctors exposing what is happening prefer the term 'transmission' to shedding. Somehow those that have had the shots are transmitting effects to those that haven't. Dr Carrie Madej said the nano-content of the 'vaccines' can 'act like an antenna' to others around them which fits perfectly with my own conclusions. This 'vaccine' transmission phenomenon was becoming known as the book went into production and I deal with this further in the Postscript.

Vaccine effects on sterility are well known. The World Health Organization was accused in 2014 of sterilising millions of women in Kenya with the evidence confirmed by the content of the vaccines involved. The same WHO behind the 'Covid' hoax admitted its involvement for more than ten years with the vaccine programme. Other countries made similar claims. Charges were lodged by Tanzania, Nicaragua, Mexico, and the Philippines. The Gardasil vaccine claimed to protect against a genital 'virus' known as HPV has also been linked to infertility. Big Pharma and the WHO (same thing) are criminal and satanic entities. Then there's the Bill Gates Foundation which is connected through funding and shared interests with 20 pharmaceutical giants and laboratories. He stands accused of directing the policy of United Nations Children's Fund (UNICEF), vaccine alliance GAVI, and other groupings, to advance the vaccine agenda and silence opposition at great cost to women and children. At the same time Gates wants to reduce the global population. Coincidence?

Great Reset = Smart Grid = new human

The Cult agenda I have been exposing for 30 years is now being openly promoted by Cult assets like Gates and Klaus Schwab of the World Economic Forum under code-terms like the 'Great Reset', 'Build Back Better' and 'a rare but narrow window of opportunity to reflect, reimagine, and reset our world'. What provided this 'rare but narrow window of opportunity'? The 'Covid' hoax did. Who created that? *They* did. My books from not that long ago warned about the planned 'Internet of Things' (IoT) and its implications for human freedom. This was the plan to connect all technology to the Internet and artificial intelligence and today we are way down that road with an estimated 36 billion devices connected to the World Wide Web and that figure is projected to be 76 billion by 2025. I further warned that the Cult planned to go beyond that to the Internet of *Everything* when the human brain was connected via AI to the Internet and Kurzweil's 'cloud'. Now we have Cult operatives like Schwab calling for precisely that under the term 'Internet of Bodies', a fusion of the physical, digital and biological into one centrally-controlled Smart Grid system which the Cult refers to as the 'Fourth Industrial Revolution'. They talk about the 'biological', but they really mean the synthetic-biological which is required to fully integrate the human body and brain into the Smart Grid and artificial intelligence planned to replace the human mind. We have everything being synthetically manipulated including the natural world through GMO and smart dust, the food we eat and the human body itself with synthetic 'vaccines'. I said in *The Answer* that we would see the Cult push for synthetic meat to replace animals and in February, 2021, the so predictable psychopath Bill Gates called for the introduction of synthetic meat to save us all from 'climate change'. The climate hoax just keeps on giving like the 'Covid' hoax. The war on meat by vegan activists is a carbon (oops, sorry) copy of the manipulation of transgender activists. They have no idea (except their inner core) that they are being used to promote and impose the agenda of the Cult or that they are only the *vehicle* and not the *reason*. This is not to say those who choose not to eat meat shouldn't be respected and supported in that right, but there are ulterior motives

for those in power. A *Forbes* article in December, 2019, highlighted the plan so beloved of Schwab and the Cult under the heading: 'What Is The Internet of Bodies? And How Is It Changing Our World?' The article said the human body is the latest data platform (remember 'our vaccine is an operating system'). *Forbes* described the plan very accurately and the words could have come straight out of my books from long before:

The Internet of Bodies (IoB) is an extension of the IoT and basically connects the human body to a network through devices that are ingested, implanted, or connected to the body in some way. Once connected, data can be exchanged, and the body and device can be remotely monitored and controlled.

They were really describing a human hive mind with human perception centrally-dictated via an AI connection as well as allowing people to be 'remotely monitored and controlled'. Everything from a fridge to a human mind could be directed from a central point by these insane psychopaths and 'Covid vaccines' are crucial to this. Forbes explained the process I mentioned earlier of holdable and wearable technology followed by implantable. The article said there were three generations of the Internet of Bodies that include:

- Body external: These are wearable devices such as Apple Watches or Fitbits that can monitor our health.

- Body internal: These include pacemakers, cochlear implants, and digital pills that go inside our bodies to monitor or control various aspects of health.

- Body embedded: The third generation of the Internet of Bodies is embedded technology where technology and the human body are melded together and have a real-time connection to a remote machine.

Forbes noted the development of the Brain Computer Interface (BCI) which merges the brain with an external device for monitoring and controlling in real-time. 'The ultimate goal is to help restore function to individuals with disabilities by using brain signals rather than conventional neuromuscular pathways.' Oh, do fuck off. The goal of brain interface technology is controlling human thought and emotion from the central point in a hive mind serving its masters wishes. Many people are now agreeing to be chipped to open doors without a key. You can recognise them because they'll be wearing a mask, social distancing and lining up for the 'vaccine'. The Cult plans a Great Reset money system after they have completed the demolition of the global economy in which 'money' will be exchanged through communication with body operating systems. Rand Corporation, a Cult-owned think tank, said of the Internet of Bodies or IoB:

> Internet of Bodies technologies fall under the broader IoT umbrella. But as the name suggests, IoB devices introduce an even more intimate interplay between humans and gadgets. IoB devices monitor the human body, collect health metrics and other personal information, and transmit those data over the Internet. Many devices, such as fitness trackers, are already in use … IoB devices … and those in development can track, record, and store users' whereabouts, bodily functions, and what they see, hear, and even think.

Schwab's World Economic Forum, a long-winded way of saying 'fascism' or 'the Cult', has gone full-on with the Internet of Bodies in the 'Covid' era. 'We're entering the era of the Internet of Bodies', it declared, 'collecting our physical data via a range of devices that can be implanted, swallowed or worn'. The result would be a huge amount of health-related data that could improve human wellbeing around the world, and prove crucial in fighting the 'Covid-19 pandemic'. Does anyone think these clowns care about 'human wellbeing' after the death and devastation their pandemic hoax has purposely caused? Schwab and co say we should move forward with the Internet of Bodies because 'Keeping track of symptoms could help us stop the spread of infection, and quickly detect new cases'. How wonderful, but keeping track' is all they are really bothered

about. Researchers were investigating if data gathered from smartwatches and similar devices could be used as viral infection alerts by tracking the user's heart rate and breathing. Schwab said in his 2018 book *Shaping the Future of the Fourth Industrial Revolution*:

> The lines between technologies and beings are becoming blurred and not just by the ability to create lifelike robots or synthetics. Instead it is about the ability of new technologies to literally become part of us. Technologies already influence how we understand ourselves, how we think about each other, and how we determine our realities. As the technologies … give us deeper access to parts of ourselves, we may begin to integrate digital technologies into our bodies.

You can see what the game is. Twenty-four hour control and people – if you could still call them that – would never know when something would go ping and take them out of circulation. It's the most obvious rush to a global fascist dictatorship and the complete submission of humanity and yet still so many are locked away in their Cult-induced perceptual coma and can't see it.

Smart Grid control centres

The human body is being transformed by the 'vaccines' and in other ways into a synthetic cyborg that can be attached to the global Smart Grid which would be controlled from a central point and other sub-locations of Grid manipulation. Where are these planned to be? Well, China for a start which is one of the Cult's biggest centres of operation. The technological control system and technocratic rule was incubated here to be unleashed across the world after the 'Covid' hoax came out of China in 2020. Another Smart Grid location that will surprise people new to this is Israel. I have exposed in *The Trigger* how Sabbatian technocrats, intelligence and military operatives were behind the horrors of 9/11 and not '19 Arab hijackers' who somehow manifested the ability to pilot big passenger airliners when instructors at puddle-jumping flying schools described some of them as a joke. The 9/11 attacks were made possible through control of civilian and military air computer systems and those of the White House, Pentagon and connected agencies. See *The Trigger* – it

will blow your mind. The controlling and coordinating force were the Sabbatian networks in Israel and the United States which by then had infiltrated the entire US government, military and intelligence system. The real name of the American Deep State is 'Sabbatian State'. Israel is a tiny country of only nine million people, but it is one of the global centres of cyber operations and fast catching Silicon Valley in importance to the Cult. Israel is known as the 'start-up nation' for all the cyber companies spawned there with the Sabbatian specialisation of 'cyber security' that I mentioned earlier which gives those companies access to computer systems of their clients in real time through 'backdoors' written into the coding when security software is downloaded. The Sabbatian centre of cyber operations outside Silicon Valley is the Israeli military Cyber Intelligence Unit, the biggest infrastructure project in Israel's history, headquartered in the desert-city of Beersheba and involving some 20,000 'cyber soldiers'. Here are located a literal army of Internet trolls scanning social media, forums and comment lists for anyone challenging the Cult agenda. The UK military has something similar with its 77th Brigade and associated operations. The Beersheba complex includes research and development centres for other Cult operations such as Intel, Microsoft, IBM, Google, Apple, Hewlett-Packard, Cisco Systems, Facebook and Motorola. Techcrunch.com ran an article about the Beersheba global Internet technology centre headlined 'Israel's desert city of Beersheba is turning into a cybertech oasis':

> The military's massive relocation of its prestigious technology units, the presence of multinational and local companies, a close proximity to Ben Gurion University and generous government subsidies are turning Beersheba into a major global cybertech hub. Beersheba has all of the ingredients of a vibrant security technology ecosystem, including Ben Gurion University with its graduate program in cybersecurity and Cyber Security Research Center, and the presence of companies such as EMC, Deutsche Telekom, PayPal, Oracle, IBM, and Lockheed Martin. It's also the future home of the INCB (Israeli National Cyber Bureau); offers a special income tax incentive for cyber security companies, and was the site for the relocation of the army's intelligence corps units.

Sabbatians have taken over the cyber world through the following process: They scan the schools for likely cyber talent and develop them at Ben Gurion University and their period of conscription in the Israeli Defense Forces when they are stationed at the Beersheba complex. When the cyber talented officially leave the army they are funded to start cyber companies with technology developed by themselves or given to them by the state. Much of this is stolen through backdoors of computer systems around the world with America top of the list. Others are sent off to Silicon Valley to start companies or join the major ones and so we have many major positions filled by apparently 'Jewish' but really Sabbatian operatives. Google, YouTube and Facebook are all run by 'Jewish' CEOs while Twitter is all but run by ultra-Zionist hedge-fund shark Paul Singer. At the centre of the Sabbatian global cyber web is the Israeli army's Unit 8200 which specialises in hacking into computer systems of other countries, inserting viruses, gathering information, instigating malfunction, and even taking control of them from a distance. A long list of Sabbatians involved with 9/11, Silicon Valley and Israeli cyber security companies are operatives of Unit 8200. This is not about Israel. It's about the Cult. Israel is planned to be a Smart Grid hub as with China and what is happening at Beersheba is not for the benefit of Jewish people who are treated disgustingly by the Sabbatian elite that control the country. A glance at the Nuremberg Codes will tell you that.

The story is much bigger than 'Covid', important as that is to where we are being taken. Now, though, it's time to really strap in. There's more … much more …

CHAPTER ELEVEN

Who controls the Cult?

Awake, arise or be forever fall'n
John Milton, *Paradise Lost*

I have exposed this far the level of the Cult conspiracy that operates in the world of the seen and within the global secret society and satanic network which operates in the shadows one step back from the seen. The story, however, goes much deeper than that.

The 'Covid' hoax is major part of the Cult agenda, but only part, and to grasp the biggest picture we have to expand our attention beyond the realm of human sight and into the infinity of possibility that we cannot see. It is from here, ultimately, that humanity is being manipulated into a state of total control by the force which dictates the actions of the Cult. How much of reality can we see? Next to damn all is the answer. We may appear to see all there is to see in the 'space' our eyes survey and observe, but little could be further from the truth. The human 'world' is only a tiny band of frequency that the body's visual and perceptual systems can decode into *perception* of a 'world'. According to mainstream science the electromagnetic spectrum is 0.005 percent of what exists in the Universe (Fig 10). The maximum estimate I have seen is 0.5 percent and either way it's miniscule. I say it is far, far, smaller even than 0.005 percent when you compare reality we see with the totality of reality that we don't. Now get this if you are new to such information: Visible light, the only band of frequency that we can see, is a *fraction* of the 0.005

percent (Fig 11 overleaf). Take this further and realise that our universe is one of infinite universes and that universes are only a fragment of overall reality – *infinite* reality. Then compare that with the almost infinitesimal frequency band of visible light or human sight. You see that humans are as near blind as it is possible to be without actually being so. Artist and filmmaker, Sergio Toporek, said:

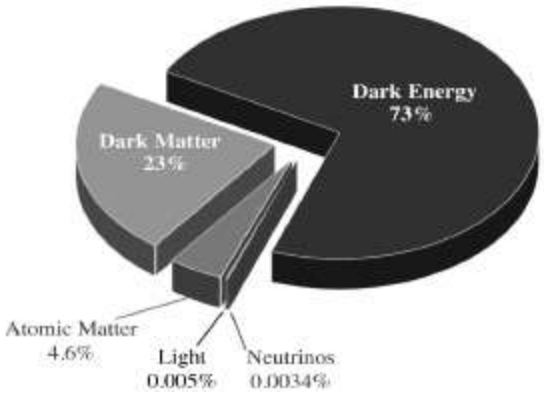


Figure 10: Humans can perceive such a tiny band of visual reality it's laughable.

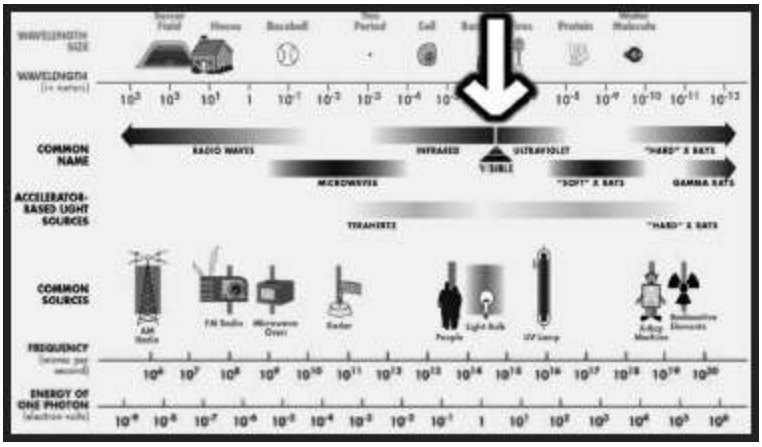


Figure 11: We can see a smear of the 0.005 percent electromagnetic spectrum, but we still know it all. Yep, makes sense.

Consider that you can see less than 1% of the electromagnetic spectrum and hear less than 1% of the acoustic spectrum. 90% of the cells in your body carry their own microbial DNA and are not 'you'. The atoms in your body are 99.9999999999999999% empty space and none of them are the ones you were born with ... Human beings have 46 chromosomes, two less than a potato.

The existence of the rainbow depends on the conical photoreceptors in your eyes; to animals without cones, the rainbow does not exist. So you don't just look at a rainbow, you create it. This is pretty amazing, especially considering that all the beautiful colours you see represent less than 1% of the electromagnetic spectrum.

Suddenly the 'world' of humans looks a very different place. Take into account, too, that Planet Earth when compared with the projected size of this single universe is the equivalent of a billionth of a pinhead. Imagine the ratio that would be when compared to infinite reality. To think that Christianity once insisted that Earth and humanity were the centre of everything. This background is vital if we are going to appreciate the nature of 'human' and how we can be manipulated by an unseen force. To human visual reality virtually *everything* is unseen and yet the prevailing perception within the institutions and so much of the public is that if we can't see it, touch it, hear it, taste it and smell it then it cannot exist. Such perception is indoctrinated and encouraged by the Cult and its agents because it isolates believers in the strictly limited, village-idiot, realm of the five senses where perceptions can be firewalled and information controlled. Most of those perpetuating the 'this-world-is-all-there-is' insanity are themselves indoctrinated into believing the same delusion. While major players and influencers know that official reality is laughable most of those in science, academia and medicine really believe the nonsense they peddle and teach succeeding generations. Those who challenge the orthodoxy are dismissed as nutters and freaks to protect the manufactured illusion from exposure. Observe the dynamic of the 'Covid' hoax and you will see how that takes the same form. The inner-circle psychopaths knows it's a gigantic scam, but almost the entirety of those imposing their fascist rules believe that 'Covid' is all that they're told it is.

Stolen identity

Ask people who they are and they will give you their name, place of birth, location, job, family background and life story. Yet that is not who they are – it is what they are *experiencing*. The difference is *absolutely crucial*. The true 'I', the eternal, infinite 'I', is consciousness,

a state of being aware. Forget 'form'. That is a vehicle for a brief experience. Consciousness does not come *from* the brain, but *through* the brain and even that is more symbolic than literal. We are awareness, pure awareness, and this is what withdraws from the body at what we call 'death' to continue our eternal beingness, *isness*, in other realms of reality within the limitlessness of infinity or the Biblical 'many mansions in my father's house'. Labels of a human life, man, woman, transgender, black, white, brown, nationality, circumstances and income are not who we are. They are what we are – awareness – is *experiencing* in a brief connection with a band of frequency we call 'human'. The labels are not the self; they are, to use the title of one of my books, a *Phantom* Self. I am not David Icke born in Leicester, England, on April 29th, 1952. I am the consciousness *having that experience*. The Cult and its non-human masters seek to convince us through the institutions of 'education', science, medicine, media and government that what we are *experiencing* is who we *are*. It's so easy to control and direct perception locked away in the bewildered illusions of the five senses with no expanded radar. Try, by contrast, doing the same with a humanity aware of its true self and its true power to consciously create its reality and experience. How is it possible to do this? We do it all day every day. If you perceive yourself as 'little me' with no power to impact upon your life and the world then your life experience will reflect that. You will hand the power you don't think you have to authority in all its forms which will use it to control your experience. This, in turn, will appear to confirm your perception of 'little me' in a self-fulfilling feedback loop. But that is what 'little me' really is – a *perception*. We are all 'big-me', infinite me, and the Cult has to make us forget that if its will is to prevail. We are therefore manipulated and pressured into self-identifying with human labels and not the consciousness/awareness *experiencing* those human labels.

The phenomenon of identity politics is a Cult-instigated manipulation technique to sub-divide previous labels into even smaller ones. A United States university employs this list of letters to

describe student identity: LGBTTQQFAGPBDSM or lesbian, gay, bisexual, transgender, transsexual, queer, questioning, flexual, asexual, gender-fuck, polyamorous, bondage/discipline, dominance/submission and sadism/masochism. I'm sure other lists are even longer by now as people feel the need to self-identity the 'I' with the minutiae of race and sexual preference. Wokers programmed by the Cult for generations believe this is about 'inclusivity' when it's really the Cult locking them away into smaller and smaller versions of Phantom Self while firewalling them from the influence of their true self, the infinite, eternal 'I'. You may notice that my philosophy which contends that we are all unique points of attention/awareness within the same infinite whole or Oneness is the ultimate non-racism. The very sense of Oneness makes the judgement of people by their body-type, colour or sexuality utterly ridiculous and confirms that racism has no understanding of reality (including anti-white racism). Yet despite my perception of life Cult agents and fast-asleep Wokers label me racist to discredit my information while they are themselves phenomenally racist and sexist. All they see is race and sexuality and they judge people as good or bad, demons or untouchables, by their race and sexuality. All they see is *Phantom Self* and perceive themselves in terms of Phantom Self. They are pawns and puppets of the Cult agenda to focus attention and self-identity in the five senses and play those identities against each other to divide and rule. Columbia University has introduced segregated graduations in another version of social distancing designed to drive people apart and teach them that different racial and cultural groups have nothing in common with each other. The last thing the Cult wants is unity. Again the pump-primers of this will be Cult operatives in the knowledge of what they are doing, but the rest are just the Phantom Self blind leading the Phantom Self blind. We *do* have something in common – we are all *the same consciousness* having different temporary experiences.

What is this 'human'?

Yes, what *is* 'human'? That is what we are supposed to be, right? I mean 'human'? True, but 'human' is the experience not the 'I'. Break it down to basics and 'human' is the way that information is processed. If we are to experience and interact with this band of frequency we call the 'world' we must have a vehicle that operates within that band of frequency. Our consciousness in its prime form cannot do that; it is way beyond the frequency of the human realm. My consciousness or awareness could not tap these keys and pick up the cup in front of me in the same way that radio station A cannot interact with radio station B when they are on different frequencies. The human body is the means through which we have that interaction. I have long described the body as a biological computer which processes information in a way that allows consciousness to experience this reality. The body is a receiver, transmitter and processor of information in a particular way that we call human. We visually perceive only the world of the five senses in a wakened state – that is the limit of the body's visual decoding system. In truth it's not even visual in the way we experience 'visual reality' as I will come to in a moment. We are 'human' because the body processes the information sources of human into a reality and behaviour system that we *perceive* as human. Why does an elephant act like an elephant and not like a human or a duck? The elephant's biological computer is a different information field and processes information according to that program into a visual and behaviour type we call an elephant. The same applies to everything in our reality. These body information fields are perpetuated through procreation (like making a copy of a software program). The Cult wants to break that cycle and intervene technologically to transform the human information field into one that will change what we call humanity. If it can change the human information field it will change the way that field processes information and change humanity both 'physically' and psychologically. Hence the *messenger* (information) RNA 'vaccines' and so much more that is targeting human genetics by changing the body's information – *messaging* – construct through food, drink, radiation, toxicity and other means.

Reality that we experience is nothing like reality as it really is in the same way that the reality people experience in virtual reality games is not the reality they are really living in. The game is only a decoded source of information that appears to be a reality. Our world is also an information construct – a *simulation* (more later). In its base form our reality is a wavefield of information much the same in theme as Wi-Fi. The five senses decode wavefield information into electrical information which they communicate to the brain to decode into holographic (illusory 'physical') information. Different parts of the brain specialise in decoding different senses and the information is fused into a reality that appears to be outside of us but is really inside the brain and the genetic structure in general (Fig 12 overleaf). DNA is a receiver-transmitter of information and a vital part of this decoding process and the body's connection to other realities. Change DNA and you change the way we decode and connect with reality – see 'Covid vaccines'. Think of computers decoding Wi-Fi. You have information encoded in a radiation field and the computer decodes that information into a very different form on the screen. You can't see the Wi-Fi until its information is made manifest on the screen and the information on the screen is inside the computer and not outside. I have just described how we decode the 'human world'. All five senses decode the waveform 'Wi-Fi' field into electrical signals and the brain (computer) constructs reality inside the brain and not outside – 'You don't just look at a rainbow, you create it'. Sound is a simple example. We don't hear sound until the brain decodes it. Waveform sound waves are picked up by the hearing sense and communicated to the brain in an electrical form to be decoded into the sounds that we hear. Everything we hear is inside the brain along with everything we see, feel, smell and taste. Words and language are waveform fields generated by our vocal chords which pass through this process until they are decoded by the brain into words that we hear. Different languages are different frequency fields or sound waves generated by vocal chords. Late British philosopher Alan Watts said:

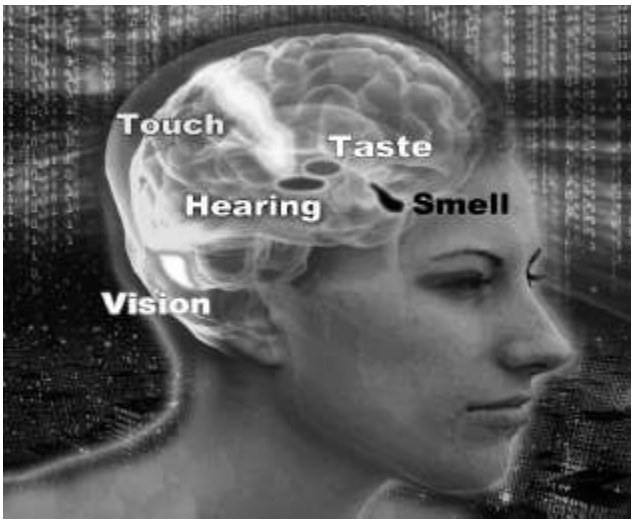


Figure 12: The brain receives information from the five senses and constructs from that our perceived reality.

[Without the brain] the world is devoid of light, heat, weight, solidity, motion, space, time or any other imaginable feature. All these phenomena are interactions, or transactions, of vibrations with a certain arrangement of neurons.

That's exactly what they are and scientist Robert Lanza describes in his book, *Biocentrism*, how we decode electromagnetic waves and energy into visual and 'physical' experience. He uses the example of a flame emitting photons, electromagnetic energy, each pulsing electrically and magnetically:

… these … invisible electromagnetic waves strike a human retina, and if (and only if) the waves happen to measure between 400 and 700 nano meters in length from crest to crest, then their energy is just right to deliver a stimulus to the 8 million cone-shaped cells in the retina.

Each in turn send an electrical pulse to a neighbour neuron, and on up the line this goes, at 250 mph, until it reaches the … occipital lobe of the brain, in the back of the head. There, a cascading complex of neurons fire from the incoming stimuli, and we subjectively perceive this experience as a yellow brightness occurring in a place we have been conditioned to call the 'external world'.

You hear what you decode

If a tree falls or a building collapses they make no noise unless someone is there to decode the energetic waves generated by the disturbance into what we call sound. Does a falling tree make a noise? Only if you hear it – *decode* it. Everything in our reality is a frequency field of information operating within the overall 'Wi-Fi' field that I call The Field. A vibrational disturbance is generated in The Field by the fields of the falling tree or building. These disturbance waves are what we decode into the sound of them falling. If no one is there to do that then neither will make any noise. Reality is created by the observer – *decoder* – and the *perceptions* of the observer affect the decoding process. For this reason different people – different *perceptions* – will perceive the same reality or situation in a different way. What one may perceive as a nightmare another will see as an opportunity. The question of why the Cult is so focused on controlling human perception now answers itself. All experienced reality is the act of decoding and we don't experience Wi-Fi until it is decoded on the computer screen. The sight and sound of an Internet video is encoded in the Wi-Fi all around us, but we don't see or hear it until the computer decodes that information. Taste, smell and touch are all phenomena of the brain as a result of the same process. We don't taste, smell or feel anything except in the brain and there are pain relief techniques that seek to block the signal from the site of discomfort to the brain because if the brain doesn't decode that signal we don't feel pain. Pain is in the brain and only appears to be at the point of impact thanks to the feedback loop between them. We don't see anything until electrical information from the sight senses is decoded in an area at the back of the brain. If that area is damaged we can go blind when our eyes are perfectly okay. So why do we go blind if we damage an eye? We damage the information processing between the waveform visual information and the visual decoding area of the brain. If information doesn't reach the brain in a form it can decode then we can't see the visual reality that it represents. What's more the brain is decoding only a fraction of the information it receives and the rest is absorbed by the

sub-conscious mind. This explanation is from the science magazine, *Wonderpedia*:

> Every second, 11 million sensations crackle along these [brain] pathways ... The brain is confronted with an alarming array of images, sounds and smells which it rigorously filters down until it is left with a manageable list of around 40. Thus 40 sensations per second make up what we perceive as reality.

The 'world' is not what people are told to believe that is it and the inner circles of the Cult *know that*.

Illusory 'physical' reality

We can only see a smear of 0.005 percent of the Universe which is only one of a vast array of universes – 'mansions' – within infinite reality. Even then the brain decodes only 40 pieces of information ('sensations') from a potential *11 million* that we receive every second. Two points strike you from this immediately: The sheer breathtaking stupidity of believing we know anything so rigidly that there's nothing more to know; and the potential for these processes to be manipulated by a malevolent force to control the reality of the population. One thing I can say for sure with no risk of contradiction is that when you can perceive an almost indescribable fraction of infinite reality there is always more to know as in tidal waves of it. Ancient Greek philosopher Socrates was so right when he said that wisdom is to know how little we know. How obviously true that is when you think that we are experiencing a physical world of solidity that is neither physical nor solid and a world of apartness when everything is connected. Cult-controlled 'science' dismisses the so-called 'paranormal' and all phenomena related to that when the 'para'-normal is perfectly normal and explains the alleged 'great mysteries' which dumbfound scientific minds. There is a reason for this. A 'scientific mind' in terms of the mainstream is a material mind, a five-sense mind imprisoned in see it, touch it, hear it, smell it and taste it. Phenomena and happenings that can't be explained that way leave the 'scientific mind' bewildered and the rule is that if they

can't account for why something is happening then it can't, by definition, be happening. I beg to differ. Telepathy is thought waves passing through The Field (think wave disturbance again) to be decoded by someone able to connect with that wavelength (information). For example: You can pick up the thought waves of a friend at any distance and at the very least that will bring them to mind. A few minutes later the friend calls you. 'My god', you say, 'that's incredible – I was just thinking of you.' Ah, but *they* were thinking of *you* before they made the call and that's what you decoded. Native peoples not entrapped in five-sense reality do this so well it became known as the 'bush telegraph'. Those known as psychics and mediums (genuine ones) are doing the same only across dimensions of reality. 'Mind over matter' comes from the fact that matter and mind are the *same*. The state of one influences the state of the other. Indeed one *and* the other are illusions. They are aspects of the same field. Paranormal phenomena are all explainable so why are they still considered 'mysteries' or not happening? Once you go down this road of understanding you begin to expand awareness beyond the five senses and that's the nightmare for the Cult.



Figure 13: Holograms are not solid, but the best ones appear to be.

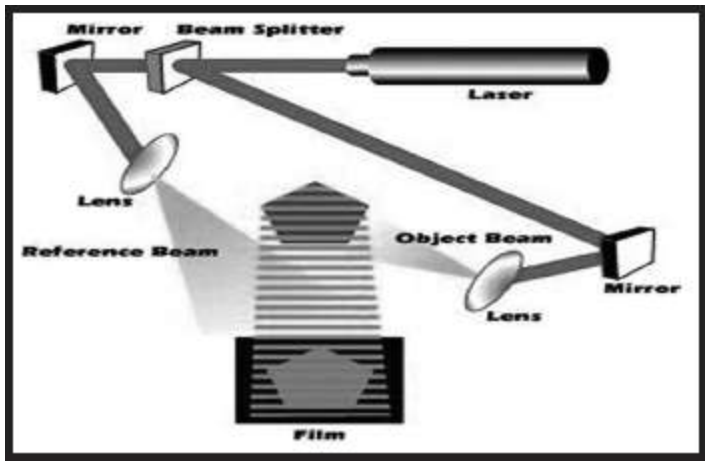


Figure 14: How holograms are created by capturing a waveform version of the subject image.

Holographic 'solidity'

Our reality is not solid, it is holographic. We are now well aware of holograms which are widely used today. Two-dimensional information is decoded into a three-dimensional reality that is not solid although can very much appear to be (Fig 13). Holograms are created with a laser divided into two parts. One goes directly onto a holographic photographic print ('reference beam') and the other takes a waveform image of the subject ('working beam') before being directed onto the print where it 'collides' with the other half of the laser (Fig 14). This creates a *waveform* interference pattern which contains the wavefield information of whatever is being photographed (Fig 15 overleaf). The process can be likened to dropping pebbles in a pond. Waves generated by each one spread out across the water to collide with the others and create a wave representation of where the stones fell and at what speed, weight and distance. A waveform interference pattern of a hologram is akin to the waveform information in The Field which the five senses decode into electrical signals to be decoded by the brain into a holographic illusory 'physical' reality. In the same way when a laser (think human attention) is directed at the waveform interference pattern a three-dimensional version of the subject is projected into apparently 'solid' reality (Fig 16). An amazing trait of holograms reveals more 'paranormal mysteries'. Information of the *whole*

hologram is encoded in waveform in every part of the interference pattern by the way they are created. This means that every *part* of a hologram is a smaller version of the whole. Cut the interference wave-pattern into four and you won't get four parts of the image. You get quarter-sized versions of the *whole* image. The body is a hologram and the same applies. Here we have the basis of acupuncture, reflexology and other forms of healing which identify representations of the whole body in all of the parts, hands, feet, ears, everywhere. Skilled palm readers can do what they do because the information of whole body is encoded in the hand. The concept of as above, so below, comes from this.



Figure 15: A waveform interference pattern that holds the information that transforms into a hologram.



Figure 16: Holographic people including 'Elvis' holographically inserted to sing a duet with Celine Dion.

The question will be asked of why, if solidity is illusory, we can't just walk through walls and each other. The resistance is not solid against solid; it is electromagnetic field against electromagnetic field and we decode this into the *experience* of solid against solid. We should also not underestimate the power of belief to dictate reality. What you believe is impossible *will be*. Your belief impacts on your decoding processes and they won't decode what you think is impossible. What we believe we perceive and what we perceive we experience. 'Can't dos' and 'impossibles' are like a firewall in a computer system that won't put on the screen what the firewall blocks. How vital that is to understanding how human experience has been hijacked. I explain in *The Answer*, *Everything You Need To Know But Have Never Been Told* and other books a long list of 'mysteries' and 'paranormal' phenomena that are not mysterious and perfectly normal once you realise what reality is and how it works. 'Ghosts' can be seen to pass through 'solid' walls because the walls are not solid and the ghost is a discarnate entity operating on a frequency so different to that of the wall that it's like two radio stations sharing the same space while never interfering with each other. I have seen ghosts do this myself. The apartness of people and objects is also an illusion. Everything is connected by the Field like all sea life is connected by the sea. It's just that within the limits of our visual reality we only 'see' holographic information and not the field of information that connects everything and from which the holographic world is made manifest. If you can only see holographic 'objects' and not the field that connects them they will appear to you as unconnected to each other in the same way that we see the computer while not seeing the Wi-Fi.

What you don't know *can* hurt you

Okay, we return to those 'two worlds' of human society and the Cult with its global network of interconnecting secret societies and satanic groups which manipulate through governments, corporations, media, religions, etc. The fundamental difference between them is *knowledge*. The idea has been to keep humanity

ignorant of the plan for its total enslavement underpinned by a crucial ignorance of reality – who we are and where we are – and how we interact with it. 'Human' should be the interaction between our expanded eternal consciousness and the five-sense body experience. We are meant to be *in* this world in terms of the five senses but not *of* this world in relation to our greater consciousness and perspective. In that state we experience the small picture of the five senses within the wider context of the big picture of awareness beyond the five senses. Put another way the five senses see the dots and expanded awareness connects them into pictures and patterns that give context to the apparently random and unconnected. Without the context of expanded awareness the five senses see only apartness and randomness with apparently no meaning. The Cult and its other-dimensional controllers seek to intervene in the frequency realm where five-sense reality is supposed to connect with expanded reality and to keep the two apart (more on this in the final chapter). When that happens five-sense mental and emotional processes are no longer influenced by expanded awareness, or the True 'I', and instead are driven by the isolated perceptions of the body's decoding systems. They are in the world *and* of it. Here we have the human plight and why humanity with its potential for infinite awareness can be so easily manipulatable and descend into such extremes of stupidity.

Once the Cult isolates five-sense mind from expanded awareness it can then program the mind with perceptions and beliefs by controlling information that the mind receives through the 'education' system of the formative years and the media perceptual bombardment and censorship of an entire lifetime. Limit perception and a sense of the possible through limiting knowledge by limiting and skewing information while censoring and discrediting that which could set people free. As the title of another of my books says *… And The Truth Shall Set You Free*. For this reason the last thing the Cult wants in circulation is the truth about anything – especially the reality of the eternal 'I' – and that's why it is desperate to control information. The Cult knows that information becomes perception

which becomes behaviour which, collectively, becomes human society. Cult-controlled and funded mainstream 'science' denies the existence of an eternal 'I' and seeks to dismiss and trash all evidence to the contrary. Cult-controlled mainstream religion has a version of 'God' that is little more than a system of control and dictatorship that employs threats of damnation in an afterlife to control perceptions and behaviour in the here and now through fear and guilt. Neither is true and it's the 'neither' that the Cult wishes to suppress. This 'neither' is that everything is an expression, a point of attention, within an infinite state of consciousness which is the real meaning of the term 'God'.

Perceptual obsession with the 'physical body' and five-senses means that 'God' becomes personified as a bearded bloke sitting among the clouds or a raging bully who loves us if we do what 'he' wants and condemns us to the fires of hell if we don't. These are no more than a 'spiritual' fairy tales to control and dictate events and behaviour through fear of this 'God' which has bizarrely made 'God-fearing' in religious circles a state to be desired. I would suggest that fearing *anything* is not to be encouraged and celebrated, but rather deleted. You can see why 'God fearing' is so beneficial to the Cult and its religions when *they* decide what 'God' wants and what 'God' demands (the Cult demands) that everyone do. As the great American comedian Bill Hicks said satirising a Christian zealot: 'I think what God meant to say.' How much of this infinite awareness ('God') that we access is decided by how far we choose to expand our perceptions, self-identity and sense of the possible. The scale of self-identity reflects itself in the scale of awareness that we can connect with and are influenced by – how much knowing and insight we have instead of programmed perception. You cannot expand your awareness into the infinity of possibility when you believe that you are little me Peter the postman or Mary in marketing and nothing more. I'll deal with this in the concluding chapter because it's crucial to how we turnaround current events.

Where the Cult came from

When I realised in the early 1990s there was a Cult network behind global events I asked the obvious question: When did it start? I took it back to ancient Rome and Egypt and on to Babylon and Sumer in Mesopotamia, the 'Land Between Two Rivers', in what we now call Iraq. The two rivers are the Tigris and Euphrates and this region is of immense historical and other importance to the Cult, as is the land called Israel only 550 miles away by air. There is much more going with deep esoteric meaning across this whole region. It's not only about 'wars for oil'. Priceless artefacts from Mesopotamia were stolen or destroyed after the American and British invasion of Iraq in 2003 justified by the lies of Boy Bush and Tony Blair (their Cult masters) about non-existent 'weapons of mass destruction'. Mesopotamia was the location of Sumer (about 5,400BC to 1,750BC), and Babylon (about 2,350BC to 539BC). Sabbatians may have become immensely influential in the Cult in modern times but they are part of a network that goes back into the mists of history. Sumer is said by historians to be the 'cradle of civilisation'. I disagree. I say it was the re-start of what we call human civilisation after cataclysmic events symbolised in part as the 'Great Flood' destroyed the world that existed before. These fantastic upheavals that I have been describing in detail in the books since the early1990s appear in accounts and legends of ancient cultures across the world and they are supported by geological and biological evidence. Stone tablets found in Iraq detailing the Sumer period say the cataclysms were caused by non-human 'gods' they call the Anunnaki. These are described in terms of extraterrestrial visitations in which knowledge supplied by the Anunnaki is said to have been the source of at least one of the world's oldest writing systems and developments in astronomy, mathematics and architecture that were way ahead of their time. I have covered this subject at length in *The Biggest Secret* and *Children of the Matrix* and the same basic 'Anunnaki' story can be found in Zulu accounts in South Africa where the late and very great Zulu high shaman Credo Mutwa told me that the Sumerian Anunnaki were known by Zulus as the Chitauri or 'children of the serpent'. See my six-hour video interview with Credo on this subject entitled *The*

Reptilian Agenda recorded at his then home near Johannesburg in 1999 which you can watch on the Ickonic media platform.

The Cult emerged out of Sumer, Babylon and Egypt (and elsewhere) and established the Roman Empire before expanding with the Romans into northern Europe from where many empires were savagely imposed in the form of Cult-controlled societies all over the world. Mass death and destruction was their calling card. The Cult established its centre of operations in Europe and European Empires were Cult empires which allowed it to expand into a global force. Spanish and Portuguese colonialists headed for Central and South America while the British and French targeted North America. Africa was colonised by Britain, France, Belgium, the Netherlands, Portugal, Spain, Italy, and Germany. Some like Britain and France moved in on the Middle East. The British Empire was by far the biggest for a simple reason. By now Britain was the headquarters of the Cult from which it expanded to form Canada, the United States, Australia and New Zealand. The Sun never set on the British Empire such was the scale of its occupation. London remains a global centre for the Cult along with Rome and the Vatican although others have emerged in Israel and China. It is no accident that the 'virus' is alleged to have come out of China while Italy was chosen as the means to terrify the Western population into compliance with 'Covid' fascism. Nor that Israel has led the world in 'Covid' fascism and mass 'vaccination'.

You would think that I would mention the United States here, but while it has been an important means of imposing the Cult's will it is less significant than would appear and is currently in the process of having what power it does have deleted. The Cult in Europe has mostly loaded the guns for the US to fire. America has been controlled from Europe from the start through Cult operatives in Britain and Europe. The American Revolution was an illusion to make it appear that America was governing itself while very different forces were pulling the strings in the form of Cult families such as the Rothschilds through the Rockefellers and other subordinates. The Rockefellers are extremely close to Bill Gates and

established both scalpel and drug 'medicine' and the World Health Organization. They play a major role in the development and circulation of vaccines through the Rockefeller Foundation on which Bill Gates said his Foundation is based. Why wouldn't this be the case when the Rockefellers and Gates are on the same team? Cult infiltration of human society goes way back into what we call history and has been constantly expanding and centralising power with the goal of establishing a global structure to dictate everything. Look how this has been advanced in great leaps with the 'Covid' hoax.

The non-human dimension

I researched and observed the comings and goings of Cult operatives through the centuries and even thousands of years as they were born, worked to promote the agenda within the secret society and satanic networks, and then died for others to replace them. Clearly there had to be a coordinating force that spanned this entire period while operatives who would not have seen the end goal in their lifetimes came and went advancing the plan over millennia. I went in search of that coordinating force with the usual support from the extraordinary synchronicity of my life which has been an almost daily experience since 1990. I saw common themes in religious texts and ancient cultures about a non-human force manipulating human society from the hidden. Christianity calls this force Satan, the Devil and demons; Islam refers to the Jinn or Djinn; Zulus have their Chitauri (spelt in other ways in different parts of Africa); and the Gnostic people in Egypt in the period around and before 400AD referred to this phenomena as the 'Archons', a word meaning rulers in Greek. Central American cultures speak of the 'Predators' among other names and the same theme is everywhere. I will use 'Archons' as a collective name for all of them. When you see how their nature and behaviour is described all these different sources are clearly talking about the same force. Gnostics described the Archons in terms of 'luminous fire' while Islam relates the Jinn to 'smokeless fire'. Some refer to beings in form that could occasionally be seen, but the most common of common theme is that they operate from

unseen realms which means almost all existence to the visual processes of humans. I had concluded that this was indeed the foundation of human control and that the Cult was operating within the human frequency band on behalf of this hidden force when I came across the writings of Gnostics which supported my conclusions in the most extraordinary way.

A sealed earthen jar was found in 1945 near the town of Nag Hammadi about 75-80 miles north of Luxor on the banks of the River Nile in Egypt. Inside was a treasure trove of manuscripts and texts left by the Gnostic people some 1,600 years earlier. They included 13 leather-bound papyrus codices (manuscripts) and more than 50 texts written in Coptic Egyptian estimated to have been hidden in the jar in the period of 400AD although the source of the information goes back much further. Gnostics oversaw the Great or Royal Library of Alexandria, the fantastic depository of ancient texts detailing advanced knowledge and accounts of human history. The Library was dismantled and destroyed in stages over a long period with the death-blow delivered by the Cult-established Roman Church in the period around 415AD. The Church of Rome was the Church of Babylon relocated as I said earlier. Gnostics were not a race. They were a way of perceiving reality. Whenever they established themselves and their information circulated the terrorists of the Church of Rome would target them for destruction. This happened with the Great Library and with the Gnostic Cathars who were burned to death by the psychopaths after a long period of oppression at the siege of the Castle of Monségur in southern France in 1244. The Church has always been terrified of Gnostic information which demolishes the official Christian narrative although there is much in the Bible that supports the Gnostic view if you read it in another way. To anyone studying the texts of what became known as the Nag Hammadi Library it is clear that great swathes of Christian and Biblical belief has its origin with Gnostics sources going back to Sumer. Gnostic themes have been twisted to manipulate the perceived reality of Bible believers. Biblical texts have been in the open for centuries where they could be changed while Gnostic

documents found at Nag Hammadi were sealed away and untouched for 1,600 years. What you see is what they wrote.

Use your *pneuma* not your *nous*

Gnosticism and Gnostic come from 'gnosis' which means knowledge, or rather *secret* knowledge, in the sense of spiritual awareness – knowledge about reality and life itself. The desperation of the Cult's Church of Rome to destroy the Gnostics can be understood when the knowledge they were circulating was the last thing the Cult wanted the population to know. Sixteen hundred years later the same Cult is working hard to undermine and silence me for the same reason. The dynamic between knowledge and ignorance is a constant. 'Time' appears to move on, but essential themes remain the same. We are told to 'use your nous', a Gnostic word for head/brain/intelligence. They said, however, that spiritual awakening or 'salvation' could only be secured by expanding awareness *beyond* what they called *nous* and into *pneuma* or Infinite Self. Obviously as I read these texts the parallels with what I have been saying since 1990 were fascinating to me. There is a universal truth that spans human history and in that case why wouldn't we be talking the same language 16 centuries apart? When you free yourself from the perception program of the five senses and explore expanded realms of consciousness you are going to connect with the same information no matter what the perceived 'era' within a manufactured timeline of a single and tiny range of manipulated frequency. Humans working with 'smart' technology or knocking rocks together in caves is only a timeline appearing to operate within the human frequency band. Expanded awareness and the knowledge it holds have always been there whether the era be Stone Age or computer age. We can only access that knowledge by opening ourselves to its frequency which the five-sense prison cell is designed to stop us doing. Gates, Fauci, Whitty, Vallance, Zuckerberg, Brin, Page, Wojcicki, Bezos, and all the others behind the 'Covid' hoax clearly have a long wait before their range of frequency can make that connection given that an open heart is

crucial to that as we shall see. Instead of accessing knowledge directly through expanded awareness it is given to Cult operatives by the secret society networks of the Cult where it has been passed on over thousands of years outside the public arena. Expanded realms of consciousness is where great artists, composers and writers find their inspiration and where truth awaits anyone open enough to connect with it. We need to go there fast.

Archon hijack

A fifth of the Nag Hammadi texts describe the existence and manipulation of the Archons led by a 'Chief Archon' they call 'Yaldabaoth', or the 'Demiurge', and this is the Christian 'Devil', 'Satan', 'Lucifer', and his demons. Archons in Biblical symbolism are the 'fallen ones' which are also referred to as fallen angels after the angels expelled from heaven according to the Abrahamic religions of Judaism, Christianity and Islam. These angels are claimed to tempt humans to 'sin' ongoing and you will see how accurate that symbolism is during the rest of the book. The theme of 'original sin' is related to the 'Fall' when Adam and Eve were 'tempted by the serpent' and fell from a state of innocence and 'obedience' (connection) with God into a state of disobedience (disconnection). The Fall is said to have brought sin into the world and corrupted everything including human nature. Yaldabaoth, the 'Lord Archon', is described by Gnostics as a 'counterfeit spirit', 'The Blind One', 'The Blind God', and 'The Foolish One'. The Jewish name for Yaldabaoth in Talmudic writings is Samael which translates as 'Poison of God', or 'Blindness of God'. You see the parallels. Yaldabaoth in Islamic belief is the Muslim Jinn devil known as Shaytan – Shaytan is Satan as the same themes are found all over the world in every religion and culture. The 'Lord God' of the Old Testament is the 'Lord Archon' of Gnostic manuscripts and that's why he's such a bloodthirsty bastard. Satan is known by Christians as 'the Demon of Demons' and Gnostics called Yaldabaoth the 'Archon of Archons'. Both are known as 'The Deceiver'. We are talking about the same 'bloke' for sure and these common themes

using different names, storylines and symbolism tell a common tale of the human plight.

Archons are referred to in Nag Hammadi documents as mind parasites, inverters, guards, gatekeepers, detainers, judges, pitiless ones and deceivers. The 'Covid' hoax alone is a glaring example of all these things. The Biblical 'God' is so different in the Old and New Testaments because they are not describing the same phenomenon. The vindictive, angry, hate-filled, 'God' of the Old Testament, known as Yahweh, is Yaldabaoth who is depicted in Cult-dictated popular culture as the 'Dark Lord', 'Lord of Time', Lord (Darth) Vader and Dormammu, the evil ruler of the 'Dark Dimension' trying to take over the 'Earth Dimension' in the Marvel comic movie, *Dr Strange*. Yaldabaoth is both the Old Testament 'god' and the Biblical 'Satan'. Gnostics referred to Yaldabaoth as the 'Great Architect of the Universe'and the Cult-controlled Freemason network calls their god 'the 'Great Architect of the Universe' (also Grand Architect). The 'Great Architect' Yaldabaoth is symbolised by the Cult as the all-seeing eye at the top of the pyramid on the Great Seal of the United States and the dollar bill. Archon is encoded in *arch*-itect as it is in *arch*-angels and *arch*-bishops. All religions have the theme of a force for good and force for evil in some sort of spiritual war and there is a reason for that – the theme is true. The Cult and its non-human masters are quite happy for this to circulate. They present themselves as the force for good fighting evil when they are really the force of evil (absence of love). The whole foundation of Cult modus operandi is inversion. They promote themselves as a force for good and anyone challenging them in pursuit of peace, love, fairness, truth and justice is condemned as a satanic force for evil. This has been the game plan throughout history whether the Church of Rome inquisitions of non-believers or 'conspiracy theorists' and 'anti-vaxxers' of today. The technique is the same whatever the timeline era.

Yaldabaoth is revolting (true)

Yaldabaoth and the Archons are said to have revolted against God with Yaldabaoth claiming to *be* God – the *All That Is*. The Old Testament 'God' (Yaldabaoth) demanded to be worshipped as such: ' *I am* the LORD, and there is none else, there is no God beside me' (Isaiah 45:5). I have quoted in other books a man who said he was the unofficial son of the late Baron Philippe de Rothschild of the Mouton-Rothschild wine producing estates in France who died in 1988 and he told me about the Rothschild 'revolt from God'. The man said he was given the name Phillip Eugene de Rothschild and we shared long correspondence many years ago while he was living under another identity. He said that he was conceived through 'occult incest' which (within the Cult) was 'normal and to be admired'. 'Phillip' told me about his experience attending satanic rituals with rich and famous people whom he names and you can see them and the wider background to Cult Satanism in my other books starting with *The Biggest Secret*. Cult rituals are interactions with Archontic 'gods'. 'Phillip' described Baron Philippe de Rothschild as 'a master Satanist and hater of God' and he used the same term 'revolt from God' associated with Yaldabaoth/Satan/Lucifer/the Devil in describing the Sabbatian Rothschild dynasty. 'I played a key role in my family's revolt from God', he said. That role was to infiltrate in classic Sabbatian style the Christian Church, but eventually he escaped the mind-prison to live another life. The Cult has been targeting religion in a plan to make worship of the Archons the global one-world religion. Infiltration of Satanism into modern 'culture', especially among the young, through music videos, stage shows and other means, is all part of this.

Nag Hammadi texts describe Yaldabaoth and the Archons in their prime form as energy – consciousness – and say they can take form if they choose in the same way that consciousness takes form as a human. Yaldabaoth is called 'formless' and represents a deeply inverted, distorted and chaotic state of consciousness which seeks to attached to humans and turn them into a likeness of itself in an attempt at assimilation. For that to happen it has to manipulate

humans into low frequency mental and emotional states that match its own. Archons can certainly appear in human form and this is the origin of the psychopathic personality. The energetic distortion Gnostics called Yaldabaoth *is* psychopathy. When psychopathic Archons take human form that human will be a psychopath as an expression of Yaldabaoth consciousness. Cult psychopaths are Archons in human form. The principle is the same as that portrayed in the 2009 *Avatar* movie when the American military travelled to a fictional Earth-like moon called Pandora in the Alpha Centauri star system to infiltrate a society of blue people, or Na'vi, by hiding within bodies that looked like the Na'vi. Archons posing as humans have a particular hybrid information field, part human, part Archon, (the ancient 'demigods') which processes information in a way that manifests behaviour to match their psychopathic evil, lack of empathy and compassion, and stops them being influenced by the empathy, compassion and love that a fully-human information field is capable of expressing. Cult bloodlines interbreed, be they royalty or dark suits, for this reason and you have their obsession with incest. Interbreeding with full-blown humans would dilute the Archontic energy field that guarantees psychopathy in its representatives in the human realm.

Gnostic writings say the main non-human forms that Archons take are *serpentine* (what I have called for decades 'reptilian' amid unbounded ridicule from the Archontically-programmed) and what Gnostics describe as 'an unborn baby or foetus with grey skin and dark, unmoving eyes'. This is an excellent representation of the ET 'Greys' of UFO folklore which large numbers of people claim to have seen and been abducted by – Zulu shaman Credo Mutwa among them. I agree with those that believe in extraterrestrial or interdimensional visitations today and for thousands of years past. No wonder with their advanced knowledge and technological capability they were perceived and worshipped as gods for technological and other 'miracles' they appeared to perform. Imagine someone arriving in a culture disconnected from the modern world with a smartphone and computer. They would be

seen as a 'god' capable of 'miracles'. The Renegade Mind, however, wants to know the source of everything and not only the way that source manifests as human or non-human. In the same way that a Renegade Mind seeks the original source material for the 'Covid virus' to see if what is claimed is true. The original source of Archons in form is consciousness – the distorted state of consciousness known to Gnostics as Yaldabaoth.

'Revolt from God' is energetic disconnection

Where I am going next will make a lot of sense of religious texts and ancient legends relating to 'Satan', Lucifer' and the 'gods'. Gnostic descriptions sync perfectly with the themes of my own research over the years in how they describe a consciousness distortion seeking to impose itself on human consciousness. I've referred to the core of infinite awareness in previous books as Infinite Awareness in Awareness of Itself. By that I mean a level of awareness that knows that it is all awareness and is aware of all awareness. From here comes the frequency of love in its true sense and balance which is what love is on one level – the balance of all forces into a single whole called Oneness and Isness. The more we disconnect from this state of love that many call 'God' the constituent parts of that Oneness start to unravel and express themselves as a part and not a whole. They become individualised as intellect, mind, selfishness, hatred, envy, desire for power over others, and such like. This is not a problem in the greater scheme in that 'God', the *All That Is*, can experience all these possibilities through different expressions of itself including humans. What we as expressions of the whole experience the *All That Is* experiences. We are the *All That Is* experiencing itself. As we withdraw from that state of Oneness we disconnect from its influence and things can get very unpleasant and very stupid. Archontic consciousness is at the extreme end of that. It has so disconnected from the influence of Oneness that it has become an inversion of unity and love, an inversion of everything, an inversion of life itself. Evil is appropriately live written backwards. Archontic consciousness is obsessed with death, an inversion of life,

and so its manifestations in Satanism are obsessed with death. They use inverted symbols in their rituals such as the inverted pentagram and cross. Sabbatians as Archontic consciousness incarnate invert Judaism and every other religion and culture they infiltrate. They seek disunity and chaos and they fear unity and harmony as they fear love like garlic to a vampire. As a result the Cult, Archons incarnate, act with such evil, psychopathy and lack of empathy and compassion disconnected as they are from the source of love. How could Bill Gates and the rest of the Archontic psychopaths do what they have to human society in the 'Covid' era with all the death, suffering and destruction involved and have no emotional consequence for the impact on others? Now you know. Why have Zuckerberg, Brin, Page, Wojcicki and company callously censored information warning about the dangers of the 'vaccine' while thousands have been dying and having severe, sometimes life-changing reactions? Now you know. Why have Tedros, Fauci, Whitty, Vallance and their like around the world been using case and death figures they're aware are fraudulent to justify lockdowns and all the deaths and destroyed lives that have come from that? Now you know. Why did Christian Drosten produce and promote a 'testing' protocol that he knew couldn't test for infectious disease which led to a global human catastrophe. Now you know. The Archontic mind doesn't give a shit (Fig 17). I personally think that Gates and major Cult insiders are a form of AI cyborg that the Archons want humans to become.

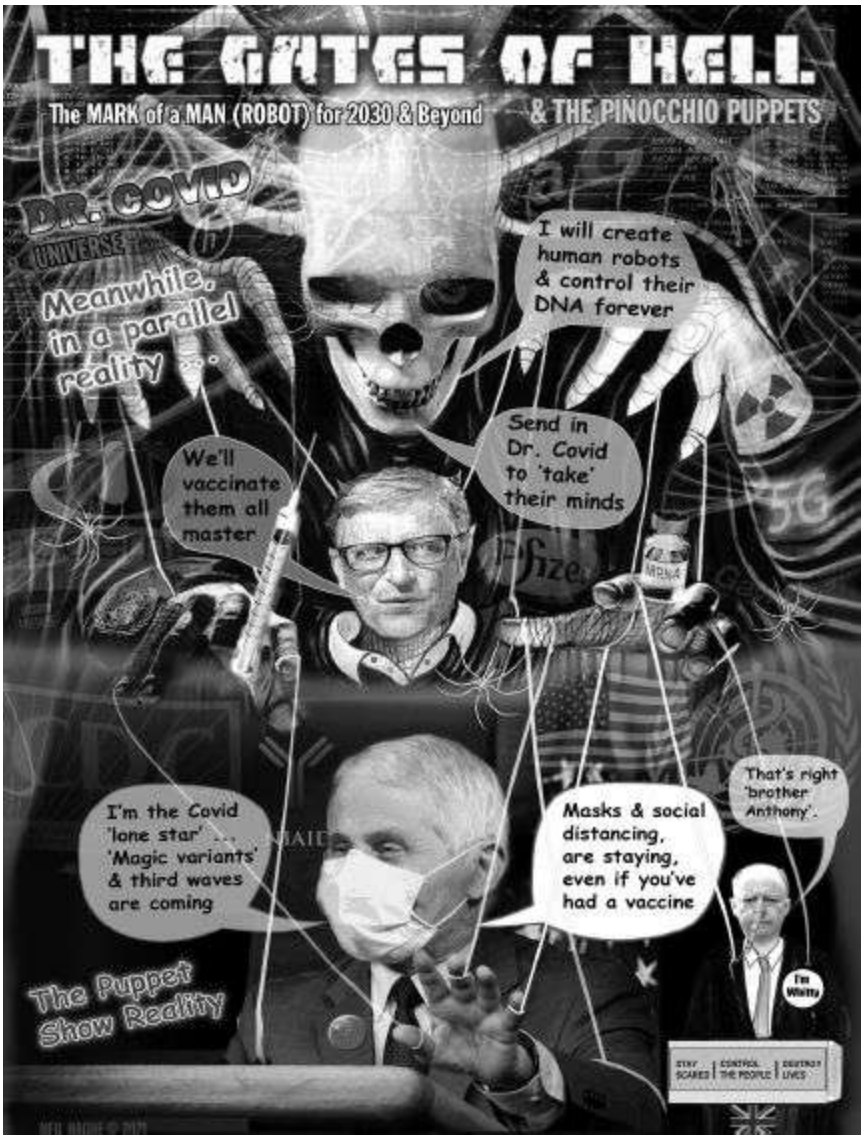


Figure 17: Artist Neil Hague's version of the 'Covid' hierarchy.

Human batteries

A state of such inversion does have its consequences, however. The level of disconnection from the Source of All means that you withdraw from that source of energetic sustenance and creativity. This means that you have to find your own supply of energetic power and it has – *us*. When the Morpheus character in the first *Matrix* movie held up a battery he spoke a profound truth when he said: 'The Matrix is a computer-generated dream world built to keep us under control in order to change the human being into one of

these.' The statement was true in all respects. We do live in a technologically-generated virtual reality simulation (more very shortly) and we have been manipulated to be an energy source for Archontic consciousness. The Disney-Pixar animated movie *Monsters, Inc*. in 2001 symbolised the dynamic when monsters in their world had no energy source and they would enter the human world to terrify children in their beds, catch the child's scream, terror (low-vibrational frequencies), and take that energy back to power the monster world. The lead character you might remember was a single giant eye and the symbolism of the Cult's all-seeing eye was obvious. Every thought and emotion is broadcast as a frequency unique to that thought and emotion. Feelings of love and joy, empathy and compassion, are high, quick, frequencies while fear, depression, anxiety, suffering and hate are low, slow, dense frequencies. Which kind do you think Archontic consciousness can connect with and absorb? In such a low and dense frequency state there's no way it can connect with the energy of love and joy. Archons can only feed off energy compatible with their own frequency and they and their Cult agents want to delete the human world of love and joy and manipulate the transmission of low vibrational frequencies through low-vibrational human mental and emotional states. *We are their energy source*. Wars are energetic banquets to the Archons – a world war even more so – and think how much low-frequency mental and emotional energy has been generated from the consequences for humanity of the 'Covid' hoax orchestrated by Archons incarnate like Gates.

The ancient practice of human sacrifice 'to the gods', continued in secret today by the Cult, is based on the same principle. 'The gods' are Archontic consciousness in different forms and the sacrifice is induced into a state of intense terror to generate the energy the Archontic frequency can absorb. Incarnate Archons in the ritual drink the blood which contains an adrenaline they crave which floods into the bloodstream when people are terrorised. Most of the sacrifices, ancient and modern, are children and the theme of 'sacrificing young virgins to the gods' is just code for children. They

have a particular pre-puberty energy that Archons want more than anything and the energy of the young in general is their target. The California Department of Education wants students to chant the names of Aztec gods (Archontic gods) once worshipped in human sacrifice rituals in a curriculum designed to encourage them to 'challenge racist, bigoted, discriminatory, imperialist/colonial beliefs', join 'social movements that struggle for social justice', and 'build new possibilities for a post-racist, post-systemic racism society'. It's the usual Woke crap that inverts racism and calls it anti-racism. In this case solidarity with 'indigenous tribes' is being used as an excuse to chant the names of 'gods' to which people were sacrificed (and still are in secret). What an example of Woke's inability to see beyond black and white, us and them, They condemn the colonisation of these tribal cultures by Europeans (quite right), but those cultures sacrificing people including children to their 'gods', and mass murdering untold numbers as the Aztecs did, is just fine. One chant is to the Aztec god Tezcatlipoca who had a man sacrificed to him in the 5th month of the Aztec calendar. His heart was cut out and he was eaten. Oh, that's okay then. Come on children … after three … Other sacrificial 'gods' for the young to chant their allegiance include Quetzalcoatl, Huitzilopochtli and Xipe Totec. The curriculum says that 'chants, affirmations, and energizers can be used to bring the class together, build unity around ethnic studies principles and values, and to reinvigorate the class following a lesson that may be emotionally taxing or even when student engagement may appear to be low'. Well, that's the cover story, anyway. Chanting and mantras are the repetition of a particular frequency generated from the vocal cords and chanting the names of these Archontic 'gods' tunes you into their frequency. That is the last thing you want when it allows for energetic synchronisation, attachment and perceptual influence. Initiates chant the names of their 'Gods' in their rituals for this very reason.

Vampires of the Woke

Paedophilia is another way that Archons absorb the energy of children. Paedophiles possessed by Archontic consciousness are used as the conduit during sexual abuse for discarnate Archons to vampire the energy of the young they desire so much. Stupendous numbers of children disappear every year never to be seen again although you would never know from the media. Imagine how much low-vibrational energy has been generated by children during the 'Covid' hoax when so many have become depressed and psychologically destroyed to the point of killing themselves. Shocking numbers of children are now taken by the state from loving parents to be handed to others. I can tell you from long experience of researching this since 1996 that many end up with paedophiles and assets of the Cult through corrupt and Cult-owned social services which in the reframing era has hired many psychopaths and emotionless automatons to do the job. Children are even stolen to order using spurious reasons to take them by the corrupt and secret (because they're corrupt) 'family courts'. I have written in detail in other books, starting with *The Biggest Secret* in 1997, about the ubiquitous connections between the political, corporate, government, intelligence and military elites (Cult operatives) and Satanism and paedophilia. If you go deep enough both networks have an interlocking leadership. The Woke mentality has been developed by the Cult for many reasons: To promote almost every aspect of its agenda; to hijack the traditional political left and turn it fascist; to divide and rule; and to target agenda pushbackers. But there are other reasons which relate to what I am describing here. How many happy and joyful Wokers do you ever see especially at the extreme end? They are a mental and psychological mess consumed by emotional stress and constantly emotionally cocked for the next explosion of indignation at someone referring to a female as a female. They are walking, talking, batteries as Morpheus might say emitting frequencies which both enslave them in low-vibrational bubbles of perceptual limitation and feed the Archons. Add to this the hatred claimed to be love; fascism claimed to 'anti-fascism', racism claimed to be 'anti-racism';

exclusion claimed to inclusion; and the abuse-filled Internet trolling. You have a purpose-built Archontic energy system with not a wind turbine in sight and all founded on Archontic *inversion*. We have whole generations now manipulated to serve the Archons with their actions and energy. They will be doing so their entire adult lives unless they snap out of their Archon-induced trance. Is it really a surprise that Cult billionaires and corporations put so much money their way? Where is the energy of joy and laughter, including laughing at yourself which is confirmation of your own emotional security? Mark Twain said: 'The human race has one really effective weapon, and that is laughter.' We must use it all the time. Woke has destroyed comedy because it has no humour, no joy, sense of irony, or self-deprecation. Its energy is dense and intense. *Mmmmm*, lunch says the Archontic frequency. Rudolf Steiner (1861-1925) was the Austrian philosopher and famous esoteric thinker who established Waldorf education or Steiner schools to treat children like unique expressions of consciousness and not minds to be programmed with the perceptions determined by authority. I'd been writing about this energy vampiring for decades when I was sent in 2016 a quote by Steiner. He was spot on:

> There are beings in the spiritual realms for whom anxiety and fear emanating from human beings offer welcome food. When humans have no anxiety and fear, then these creatures starve. If fear and anxiety radiates from people and they break out in panic, then these creatures find welcome nutrition and they become more and more powerful. These beings are hostile towards humanity. Everything that feeds on negative feelings, on anxiety, fear and superstition, despair or doubt, are in reality hostile forces in super-sensible worlds, launching cruel attacks on human beings, while they are being fed ... These are exactly the feelings that belong to contemporary culture and materialism; because it estranges people from the spiritual world, it is especially suited to evoke hopelessness and fear of the unknown in people, thereby calling up the above mentioned hostile forces against them.

Pause for a moment from this perspective and reflect on what has happened in the world since the start of 2020. Not only will pennies drop, but billion dollar bills. We see the same theme from Don Juan Matus, a Yaqui Indian shaman in Mexico and the information source for Peruvian-born writer, Carlos Castaneda, who wrote a series of

books from the 1960s to 1990s. Don Juan described the force manipulating human society and his name for the Archons was the predator:

> We have a predator that came from the depths of the cosmos and took over the rule of our lives. Human beings are its prisoners. The predator is our lord and master. It has rendered us docile, helpless. If we want to protest, it suppresses our protest. If we want to act independently, it demands that we don't do so ... indeed we are held prisoner!
>
> They took us over because we are food to them, and they squeeze us mercilessly because we are their sustenance. Just as we rear chickens in coops, the predators rear us in human coops, humaneros. Therefore, their food is always available to them.
>
> Different cultures, different eras, same recurring theme.

The 'ennoia' dilemma

Nag Hammadi Gnostic manuscripts say that Archon consciousness has no 'ennoia'. This is directly translated as 'intentionality', but I'll use the term 'creative imagination'. The *All That Is* in awareness of itself is the source of all creativity – all possibility – and the more disconnected you are from that source the more you are subsequently denied 'creative imagination'. Given that Archon consciousness is almost entirely disconnected it severely lacks creativity and has to rely on far more mechanical processes of thought and exploit the creative potential of those that do have 'ennoia'. You can see cases of this throughout human society. Archon consciousness almost entirely dominates the global banking system and if we study how that system works you will appreciate what I mean. Banks manifest 'money' out of nothing by issuing lines of 'credit' which is 'money' that has never, does not, and will never exist except in theory. It's a confidence trick. If you think 'credit' figures-on-a-screen 'money' is worth anything you accept it as payment. If you don't then the whole system collapses through lack of confidence in the value of that 'money'. Archontic bankers with no 'ennoia' are 'lending' 'money' that doesn't exist to humans that *do* have creativity – those that have the inspired ideas and create businesses and products. Archon banking feeds off human creativity

which it controls through 'money' creation and debt. Humans have the creativity and Archons exploit that for their own benefit and control while having none themselves. Archon Internet platforms like Facebook claim joint copyright of everything that creative users post and while Archontic minds like Zuckerberg may officially head that company it will be human creatives on the staff that provide the creative inspiration. When you have limitless 'money' you can then buy other companies established by creative humans. Witness the acquisition record of Facebook, Google and their like. Survey the Archon-controlled music industry and you see non-creative dark suit executives making their fortune from the human creativity of their artists. The cases are endless. Research the history of people like Gates and Zuckerberg and how their empires were built on exploiting the creativity of others. Archon minds cannot create out of nothing, but they are skilled (because they have to be) in what Gnostic texts call 'countermimicry'. They can imitate, but not innovate. Sabbatians trawl the creativity of others through backdoors they install in computer systems through their cybersecurity systems. Archon-controlled China is globally infamous for stealing intellectual property and I remember how Hong Kong, now part of China, became notorious for making counterfeit copies of the creativity of others – 'countermimicry'. With the now pervasive and all-seeing surveillance systems able to infiltrate any computer you can appreciate the potential for Archons to vampire the creativity of humans. Author John Lamb Lash wrote in his book about the Nag Hammadi texts, *Not In His Image*:

> Although they cannot originate anything, because they lack the divine factor of ennoia (intentionality), Archons can imitate with a vengeance. Their expertise is simulation (HAL, virtual reality). The Demiurge [Yaldabaoth] fashions a heaven world copied from the fractal patterns [of the original] ... His construction is celestial kitsch, like the fake Italianate villa of a Mafia don complete with militant angels to guard every portal.

This brings us to something that I have been speaking about since the turn of the millennium. Our reality is a simulation; a virtual reality that we think is real. No, I'm not kidding.

Human reality? Well, virtually

I had pondered for years about whether our reality is 'real' or some kind of construct. I remembered being immensely affected on a visit as a small child in the late 1950s to the then newly-opened Planetarium on the Marylebone Road in London which is now closed and part of the adjacent Madame Tussauds wax museum. It was in the middle of the day, but when the lights went out there was the night sky projected in the Planetarium's domed ceiling and it appeared to be so real. The experience never left me and I didn't know why until around the turn of the millennium when I became certain that our 'night sky' and entire reality is a projection, a virtual reality, akin to the illusory world portrayed in the *Matrix* movies. I looked at the sky one day in this period and it appeared to me like the domed roof of the Planetarium. The release of the first *Matrix* movie in 1999 also provided a synchronistic and perfect visual representation of where my mind had been going for a long time. I hadn't come across the Gnostic Nag Hammadi texts then. When I did years later the correlation was once again astounding. As I read Gnostic accounts from 1,600 years and more earlier it was clear that they were describing the same simulation phenomenon. They tell how the Yaldabaoth 'Demiurge' and Archons created a 'bad copy' of original reality to rule over all that were captured by its illusions and the body was a prison to trap consciousness in the 'bad copy' fake reality. Read how Gnostics describe the 'bad copy' and update that to current times and they are referring to what we would call today a virtual reality simulation.

Author John Lamb Lash said 'the Demiurge fashions a heaven world copied from the fractal patterns' of the original through expertise in 'HAL' or virtual reality simulation. Fractal patterns are part of the energetic information construct of our reality, a sort of blueprint. If these patterns were copied in computer terms it would indeed give you a copy of a 'natural' reality in a non-natural frequency and digital form. The principle is the same as making a copy of a website. The original website still exists, but now you can change the copy version to make it whatever you like and it can

become very different to the original website. Archons have done this with our reality, a *synthetic* copy of prime reality that still exists beyond the frequency walls of the simulation. Trapped within the illusions of this synthetic Matrix, however, were and are human consciousness and other expressions of prime reality and this is why the Archons via the Cult are seeking to make the human body synthetic and give us synthetic AI minds to complete the job of turning the entire reality synthetic including what we perceive to be the natural world. To quote Kurzweil: 'Nanobots will infuse all the matter around us with information. Rocks, trees, everything will become these intelligent creatures.' Yes, *synthetic* 'creatures' just as 'Covid' and other genetically-manipulating 'vaccines' are designed to make the human body synthetic. From this perspective it is obvious why Archons and their Cult are so desperate to infuse synthetic material into every human with their 'Covid' scam.

Let there be (electromagnetic) light

Yaldabaoth, the force that created the simulation, or Matrix, makes sense of the Gnostic reference to 'The Great Architect' and its use by Cult Freemasonry as the name of its deity. The designer of the Matrix in the movies is called 'The Architect' and that trilogy is jam-packed with symbolism relating to these subjects. I have contended for years that the angry Old Testament God (Yaldabaoth) is the 'God' being symbolically 'quoted' in the opening of Genesis as 'creating the world'. This is not the creation of prime reality – it's the creation of the *simulation*. The Genesis 'God' says: 'Let there be Light: and there was light.' But what is this 'Light'? I have said for decades that the speed of light (186,000 miles per second) is not the fastest speed possible as claimed by mainstream science and is in fact the frequency walls or outer limits of the Matrix. You can't have a fastest or slowest anything within all possibility when everything is possible. The human body is encoded to operate within the speed of light or *within the simulation* and thus we see only the tiny frequency band of visible *light*. Near-death experiencers who perceive reality outside the body during temporary 'death' describe a very different

form of light and this is supported by the Nag Hammadi texts. Prime reality beyond the simulation ('Upper Aeons' to the Gnostics) is described as a realm of incredible beauty, bliss, love and harmony – a realm of 'watery light' that is so powerful 'there are no shadows'. Our false reality of Archon control, which Gnostics call the 'Lower Aeons', is depicted as a realm with a different kind of 'light' and described in terms of chaos, 'Hell', 'the Abyss' and 'Outer Darkness', where trapped souls are tormented and manipulated by demons (relate that to the 'Covid' hoax alone). The watery light theme can be found in near-death accounts and it is not the same as *simulation* 'light' which is electromagnetic or radiation light within the speed of light – the 'Lower Aeons'. Simulation 'light' is the 'luminous fire' associated by Gnostics with the Archons. The Bible refers to Yaldabaoth as 'that old serpent, called the Devil, and Satan, which deceiveth the whole world' (Revelation 12:9). I think that making a simulated copy of prime reality ('countermimicry') and changing it dramatically while all the time manipulating humanity to believe it to be real could probably meet the criteria of deceiving the whole world. Then we come to the Cult god Lucifer – the *Light Bringer*. Lucifer is symbolic of Yaldabaoth, the bringer of radiation light that forms the bad copy simulation within the speed of light. 'He' is symbolised by the lighted torch held by the Statue of Liberty and in the name 'Illuminati'. Sabbatian-Frankism declares that Lucifer is the true god and Lucifer is the real god of Freemasonry honoured as their 'Great or Grand Architect of the Universe' (simulation).

I would emphasise, too, the way Archontic technologically-generated luminous fire of radiation has deluged our environment since I was a kid in the 1950s and changed the nature of The Field with which we constantly interact. Through that interaction technological radiation is changing us. The Smart Grid is designed to operate with immense levels of communication power with 5G expanding across the world and 6G, 7G, in the process of development. Radiation is the simulation and the Archontic manipulation system. Why wouldn't the Archon Cult wish to unleash radiation upon us to an ever-greater extreme to form

Kurzweil's 'cloud'? The plan for a synthetic human is related to the need to cope with levels of radiation beyond even anything we've seen so far. Biological humans would not survive the scale of radiation they have in their script. The Smart Grid is a technological sub-reality within the technological simulation to further disconnect five-sense perception from expanded consciousness. It's a technological prison of the mind.

Infusing the 'spirit of darkness'

A recurring theme in religion and native cultures is the manipulation of human genetics by a non-human force and most famously recorded as the biblical 'sons of god' (the god*s* plural in the original) who interbred with the daughters of men. The Nag Hammadi *Apocryphon of John* tells the same story this way:

> He [Yaldabaoth] sent his angels [Archons/demons] to the daughters of men, that they might take some of them for themselves and raise offspring for their enjoyment. And at first they did not succeed. When they had no success, they gathered together again and they made a plan together ... And the angels changed themselves in their likeness into the likeness of their mates, filling them with the spirit of darkness, which they had mixed for them, and with evil ... And they took women and begot children out of the darkness according to the likeness of their spirit.

Possession when a discarnate entity takes over a human body is an age-old theme and continues today. It's very real and I've seen it. Satanic and secret society rituals can create an energetic environment in which entities can attach to initiates and I've heard many stories of how people have changed their personality after being initiated even into lower levels of the Freemasons. I have been inside three Freemasonic temples, one at a public open day and two by just walking in when there was no one around to stop me. They were in Ryde, the town where I live, Birmingham, England, when I was with a group, and Boston, Massachusetts. They all felt the same energetically – dark, dense, low-vibrational and sinister. Demonic attachment can happen while the initiate has no idea what is going on. To them it's just a ritual to get in the Masons and do a bit of good

business. In the far more extreme rituals of Satanism human possession is even more powerful and they are designed to make possession possible. The hierarchy of the Cult is dictated by the power and perceived status of the possessing Archon. In this way the Archon hierarchy becomes the Cult hierarchy. Once the entity has attached it can influence perception and behaviour and if it attaches to the extreme then so much of its energy (information) infuses into the body information field that the hologram starts to reflect the nature of the possessing entity. This is the *Exorcist* movie type of possession when facial features change and it's known as shapeshifting. Islam's Jinn are said to be invisible tricksters who change shape, 'whisper', confuse and take human form. These are all traits of the Archons and other versions of the same phenomenon. Extreme possession could certainty infuse the 'spirit of darkness' into a partner during sex as the Nag Hammadi texts appear to describe. Such an infusion can change genetics which is also energetic information. Human genetics is information and the 'spirit of darkness' is information. Mix one with the other and change must happen. Islam has the concept of a 'Jinn baby' through possession of the mother and by Jinn taking human form. There are many ways that human genetics can be changed and remember that Archons have been aware all along of advanced techniques to do this. What is being done in human society today – and far more – was known about by Archons at the time of the 'fallen ones' and their other versions described in religions and cultures.

Archons and their human-world Cult are obsessed with genetics as we see today and they know this dictates how information is processed into perceived reality during a human life. They needed to produce a human form that would decode the simulation and this is symbolically known as 'Adam and Eve' who left the 'garden' (prime reality) and 'fell' into Matrix reality. The simulation is not a 'physical' construct (there is no 'physical'); it is a source of information. Think Wi-Fi again. The simulation is an energetic field encoded with information and body-brain systems are designed to decode that information encoded in wave or frequency form which

is transmitted to the brain as electrical signals. These are decoded by the brain to construct our sense of reality – an illusory 'physical' world that only exists in the brain or the mind. Virtual reality games mimic this process using the same sensory decoding system. Information is fed to the senses to decode a virtual reality that can appear so real, but isn't (Figs 18 and 19). Some scientists believe – and I agree with them – that what we perceive as 'physical' reality only exists when we are looking or observing. The act of perception or focus triggers the decoding systems which turn waveform information into holographic reality. When we are not observing something our reality reverts from a holographic state to a waveform state. This relates to the same principle as a falling tree not making a noise unless someone is there to hear it or decode it. The concept makes sense from the simulation perspective. A computer is not decoding all the information in a Wi-Fi field all the time and only decodes or brings into reality on the screen that part of Wi-Fi that it's decoding – focusing upon – at that moment.



Figure 18: Virtual reality technology 'hacks' into the body's five-sense decoding system.



Figure 19: The result can be experienced as very 'real'.

Interestingly, Professor Donald Hoffman at the Department of Cognitive Sciences at the University of California, Irvine, says that our experienced reality is like a computer interface that shows us only the level with which we interact while hiding all that exists beyond it: 'Evolution shaped us with a user interface that hides the truth. Nothing that we see is the truth – the very language of space and time and objects is the wrong language to describe reality.' He is correct in what he says on so many levels. Space and time are not a universal reality. They are a phenomenon of decoded *simulation* reality as part of the process of enslaving our sense of reality. Near-death experiencers report again and again how space and time did not exist as we perceive them once they were free of the body – body decoding systems. You can appreciate from this why Archons and their Cult are so desperate to entrap human attention in the five senses where we are in the Matrix and of the Matrix. Opening your mind to expanded states of awareness takes you beyond the information confines of the simulation and you become aware of knowledge and insights denied to you before. This is what we call 'awakening' – *awakening from the Matrix* – and in the final chapter I will relate this to current events.

Where are the 'aliens'?

A simulation would explain the so-called 'Fermi Paradox' named after Italian physicist Enrico Fermi (1901-1954) who created the first nuclear reactor. He considered the question of why there is such a lack of extraterrestrial activity when there are so many stars and planets in an apparently vast universe; but what if the night sky that we see, or think we do, is a simulated projection as I say? If you control the simulation and your aim is to hold humanity fast in essential ignorance would you want other forms of life including advanced life coming and going sharing information with humanity? Or would you want them to believe they were isolated and apparently alone? Themes of human isolation and apartness are common whether they be the perception of a lifeless universe or the fascist isolation laws of the 'Covid' era. Paradoxically the very

existence of a simulation means that we are not alone when some force had to construct it. My view is that experiences that people have reported all over the world for centuries with Reptilians and Grey entities are Archon phenomena as Nag Hammadi texts describe; and that benevolent 'alien' interactions are non-human groups that come in and out of the simulation by overcoming Archon attempts to keep them out. It should be highlighted, too, that Reptilians and Greys are obsessed with *genetics* and *technology* as related by cultural accounts and those who say they have been abducted by them. Technology is their way of overcoming some of the limitations in their creative potential and our technology-driven and controlled human society of today is *arch*etypical Archon-Reptilian-Grey modus operandi. Technocracy is really *Archon*tocracy. The Universe does not have to be as big as it appears with a simulation. There is no space or distance only information decoded into holographic reality. What we call 'space' is only the absence of holographic 'objects' and that 'space' is The Field of energetic information which connects everything into a single whole. The same applies with the artificially-generated information field of the simulation. The Universe is not big or small as a physical reality. It is decoded information, that's all, and its perceived size is decided by the way the simulation is encoded to make it appear. The entire night sky as we perceive it only exists in our brain and so where are those 'millions of light years'? The 'stars' on the ceiling of the Planetarium looked a vast distance away.

There's another point to mention about 'aliens'. I have been highlighting since the 1990s the plan to stage a fake 'alien invasion' to justify the centralisation of global power and a world military. Nazi scientist Werner von Braun, who was taken to America by Operation Paperclip after World War Two to help found NASA, told his American assistant Dr Carol Rosin about the Cult agenda when he knew he was dying in 1977. Rosin said that he told her about a sequence that would lead to total human control by a one-world government. This included threats from terrorism, rogue nations, meteors and asteroids before finally an 'alien invasion'. All of these

things, von Braun said, would be bogus and what I would refer to as a No-Problem-Reaction-Solution. Keep this in mind when 'the aliens are coming' is the new mantra. The aliens are not coming – they are *already here* and they have infiltrated human society while looking human. French-Canadian investigative journalist Serge Monast said in 1994 that he had uncovered a NASA/military operation called Project Blue Beam which fits with what Werner von Braun predicted. Monast died of a 'heart attack' in 1996 the day after he was arrested and spent a night in prison. He was 51. He said Blue Beam was a plan to stage an alien invasion that would include religious figures beamed holographically into the sky as part of a global manipulation to usher in a 'new age' of worshipping what I would say is the Cult 'god' Yaldabaoth in a one-world religion. Fake holographic asteroids are also said to be part of the plan which again syncs with von Braun. How could you stage an illusory threat from asteroids unless they were holographic inserts? This is pretty straightforward given the advanced technology outside the public arena and the fact that our 'physical' reality is holographic anyway. Information fields would be projected and we would decode them into the illusion of a 'physical' asteroid. If they can sell a global 'pandemic' with a 'virus' that doesn't exist what will humans not believe if government and media tell them?

All this is particularly relevant as I write with the Pentagon planning to release in June, 2021, information about 'UFO sightings'. I have been following the UFO story since the early 1990s and the common theme throughout has been government and military denials and cover up. More recently, however, the Pentagon has suddenly become more talkative and apparently open with Air Force pilot radar images released of unexplained craft moving and changing direction at speeds well beyond anything believed possible with human technology. Then, in March, 2021, former Director of National Intelligence John Ratcliffe said a Pentagon report months later in June would reveal a great deal of information about UFO sightings unknown to the public. He said the report would have 'massive implications'. The order to do this was included bizarrely

in a $2.3 trillion 'coronavirus' relief and government funding bill passed by the Trump administration at the end of 2020. I would add some serious notes of caution here. I have been pointing out since the 1990s that the US military and intelligence networks have long had craft – 'flying saucers' or anti-gravity craft – which any observer would take to be extraterrestrial in origin. Keeping this knowledge from the public allows craft flown by *humans* to be perceived as alien visitations. I am not saying that 'aliens' do not exist. I would be the last one to say that, but we have to be streetwise here. President Ronald Reagan told the UN General Assembly in 1987: 'I occasionally think how quickly our differences worldwide would vanish if we were facing an alien threat from outside this world.' That's the idea. Unite against a common 'enemy' with a common purpose behind your 'saviour force' (the Cult) as this age-old technique of mass manipulation goes global.

Science moves this way …

I could find only one other person who was discussing the simulation hypothesis publicly when I concluded it was real. This was Nick Bostrom, a Swedish-born philosopher at the University of Oxford, who has explored for many years the possibility that human reality is a computer simulation although his version and mine are not the same. Today the simulation and holographic reality hypothesis have increasingly entered the scientific mainstream. Well, the more open-minded mainstream, that is. Here are a few of the ever-gathering examples. American nuclear physicist Silas Beane led a team of physicists at the University of Bonn in Germany pursuing the question of whether we live in a simulation. They concluded that we probably do and it was likely based on a lattice of cubes. They found that cosmic rays align with that specific pattern. The team highlighted the Greisen–Zatsepin–Kuzmin (GZK) limit which refers to cosmic ray particle interaction with cosmic background radiation that creates an apparent boundary for cosmic ray particles. They say in a paper entitled 'Constraints on the Universe as a Numerical Simulation' that this 'pattern of constraint' is exactly what you

would find with a computer simulation. They also made the point that a simulation would create its own 'laws of physics' that would limit possibility. I've been making the same point for decades that the *perceived* laws of physics relate only to this reality, or what I would later call the simulation. When designers write codes to create computer and virtual reality games they are the equivalent of the laws of physics for that game. Players interact within the limitations laid out by the coding. In the same way those who wrote the codes for the simulation decided the laws of physics that would apply. These can be overridden by expanded states of consciousness, but not by those enslaved in only five-sense awareness where simulation codes rule. Overriding the codes is what people call 'miracles'. They are not. They are bypassing the encoded limits of the simulation. A population caught in simulation perception would have no idea that this was their plight. As the Bonn paper said: 'Like a prisoner in a pitch-black cell we would not be able to see the "walls" of our prison,' That's true if people remain mesmerised by the five senses. Open to expanded awareness and those walls become very clear. The main one is the speed of light.

American theoretical physicist James Gates is another who has explored the simulation question and found considerable evidence to support the idea. Gates was Professor of Physics at the University of Maryland, Director of The Center for String and Particle Theory, and on Barack Obama's Council of Advisors on Science and Technology. He and his team found *computer codes* of digital data embedded in the fabric of our reality. They relate to on-off electrical charges of 1 and 0 in the binary system used by computers. 'We have no idea what they are doing there', Gates said. They found within the energetic fabric mathematical sequences known as error-correcting codes or block codes that 'reboot' data to its original state or 'default settings' when something knocks it out of sync. Gates was asked if he had found a set of equations embedded in our reality indistinguishable from those that drive search engines and browsers and he said: 'That is correct.' Rich Terrile, director of the Centre for Evolutionary Computation and Automated Design at NASA's Jet

Propulsion Laboratory, has said publicly that he believes the Universe is a digital hologram that must have been created by a form of intelligence. I agree with that in every way. Waveform information is delivered electrically by the senses to the brain which constructs a *digital* holographic reality that we call the 'world'. This digital level of reality can be read by the esoteric art of numerology. Digital holograms are at the cutting edge of holographics today. We have digital technology everywhere designed to access and manipulate our digital level of perceived reality. Synthetic mRNA in 'Covid vaccines' has a digital component to manipulate the body's digital 'operating system'.

Reality is numbers

How many know that our reality can be broken down to numbers and codes that are the same as computer games? Max Tegmark, a physicist at the Massachusetts Institute of Technology (MIT), is the author of *Our Mathematical Universe* in which he lays out how reality can be entirely described by numbers and maths in the way that a video game is encoded with the 'physics' of computer games. Our world and computer virtual reality are essentially the same. Tegmark imagines the perceptions of characters in an advanced computer game when the graphics are so good they don't know they are in a game. They think they can bump into real objects (electromagnetic resistance in our reality), fall in love and feel emotions like excitement. When they began to study the apparently 'physical world' of the video game they would realise that everything was made of pixels (which have been found in our energetic reality as must be the case when on one level our world is digital). What computer game characters thought was physical 'stuff', Tegmark said, could actually be broken down into numbers:

> And we're exactly in this situation in our world. We look around and it doesn't seem that mathematical at all, but everything we see is made out of elementary particles like quarks and electrons. And what properties does an electron have? Does it have a smell or a colour or a texture? No! ... We physicists have come up with geeky names for [Electron] properties, like

electric charge, or spin, or lepton number, but the electron doesn't care what we call it, the properties are just numbers.

This is the illusory reality Gnostics were describing. This is the simulation. The A, C, G, and T codes of DNA have a binary value – A and C = 0 while G and T = 1. This has to be when the simulation is digital and the body must be digital to interact with it. Recurring mathematical sequences are encoded throughout reality and the body. They include the Fibonacci sequence in which the two previous numbers are added to get the next one, as in ... 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, etc. The sequence is encoded in the human face and body, proportions of animals, DNA, seed heads, pine cones, trees, shells, spiral galaxies, hurricanes and the number of petals in a flower. The list goes on and on. There are fractal patterns – a 'never-ending pattern that is infinitely complex and self-similar across all scales in the as above, so below, principle of holograms. These and other famous recurring geometrical and mathematical sequences such as Phi, Pi, Golden Mean, Golden Ratio and Golden Section are *computer codes* of the simulation. I had to laugh and give my head a shake the day I finished this book and it went into the production stage. I was sent an article in *Scientific American* published in April, 2021, with the headline 'Confirmed! We Live in a Simulation'. Two decades after I first said our reality is a simulation and the speed of light is it's outer limit the article suggested that we do live in a simulation and that the speed of light is its outer limit. I left school at 15 and never passed a major exam in my life while the writer was up to his eyes in qualifications. As I will explain in the final chapter *knowing* is far better than thinking and they come from very different sources. The article rightly connected the speed of light to the processing speed of the 'Matrix' and said what has been in my books all this time … 'If we are in a simulation, as it appears, then space is an abstract property written in code. It is not real'. No it's not and if we live in a simulation something created it and it wasn't *us*. 'That David Icke says we are manipulated by aliens' – he's crackers.'

Wow …

The reality that humanity thinks is so real is an illusion. Politicians, governments, scientists, doctors, academics, law enforcement, media, school and university curriculums, on and on, are all founded on a world that *does not exist* except as a simulated prison cell. Is it such a stretch to accept that 'Covid' doesn't exist when our entire 'physical' reality doesn't exist? Revealed here is the knowledge kept under raps in the Cult networks of compartmentalised secrecy to control humanity's sense of reality by inducing the population to believe in a reality that's not real. If it wasn't so tragic in its experiential consequences the whole thing would be hysterically funny. None of this is new to Renegade Minds. Ancient Greek philosopher Plato (about 428 to about 347BC) was a major influence on Gnostic belief and he described the human plight thousands of years ago with his Allegory of the Cave. He told the symbolic story of prisoners living in a cave who had never been outside. They were chained and could only see one wall of the cave while behind them was a fire that they could not see. Figures walked past the fire casting shadows on the prisoners' wall and those moving shadows became their sense of reality. Some prisoners began to study the shadows and were considered experts on them (today's academics and scientists), but what they studied was only an illusion (today's academics and scientists). A prisoner escaped from the cave and saw reality as it really is. When he returned to report this revelation they didn't believe him, called him mad and threatened to kill him if he tried to set them free. Plato's tale is not only a brilliant analogy of the human plight and our illusory reality. It describes, too, the dynamics of the 'Covid' hoax. I have only skimmed the surface of these subjects here. The aim of this book is to crisply connect all essential dots to put what is happening today into its true context. All subject areas and their connections in this chapter are covered in great evidential detail in *Everything You Need To Know, But Have Never Been Told* and *The Answer*.

They say that bewildered people 'can't see the forest for the trees'. Humanity, however, can't see the forest for the *twigs*. The five senses

see only twigs while Renegade Minds can see the forest and it's the forest where the answers lie with the connections that reveals. Breaking free of perceptual programming so the forest can be seen is the way we turn all this around. Not breaking free is how humanity got into this mess. The situation may seem hopeless, but I promise you it's not. We are a perceptual heartbeat from paradise if only we knew.

CHAPTER TWELVE

Escaping Wetiko

Life is simply a vacation from the infinite
Dean Cavanagh

Renegade Minds weave the web of life and events and see common themes in the apparently random. They are always there if you look for them and their pursuit is aided by incredible synchronicity that comes when your mind is open rather than mesmerised by what it thinks it can see.

Infinite awareness is infinite possibility and the more of infinite possibility that we access the more becomes infinitely possible. That may be stating the apparently obvious, but it is a devastatingly-powerful fact that can set us free. We are a point of attention within an infinity of consciousness. The question is how much of that infinity do we choose to access? How much knowledge, insight, awareness, wisdom, do we want to connect with and explore? If your focus is only in the five senses you will be influenced by a fraction of infinite awareness. I mean a range so tiny that it gives new meaning to infinitesimal. Limitation of self-identity and a sense of the possible limit accordingly your range of consciousness. We are what we think we are. Life is what we think it is. The dream is the dreamer and the dreamer is the dream. Buddhist philosophy puts it this way: 'As a thing is viewed, so it appears.' Most humans live in the realm of touch, taste, see, hear, and smell and that's the limit of their sense of the possible and sense of self. Many will follow a religion and speak of a God in his heaven, but their lives are still

dominated by the five senses in their perceptions and actions. The five senses become the arbiter of everything. When that happens all except a smear of infinity is sealed away from influence by the rigid, unyielding, reality bubbles that are the five-sense human or Phantom Self. Archon Cult methodology is to isolate consciousness within five-sense reality – the simulation – and then program that consciousness with a sense of self and the world through a deluge of life-long information designed to instil the desired perception that allows global control. Efforts to do this have increased dramatically with identity politics as identity bubbles are squeezed into the minutiae of five-sense detail which disconnect people even more profoundly from the infinite 'I'.

Five-sense focus and self-identity are like a firewall that limits access to the infinite realms. You only perceive one radio or television station and no other. We'll take that literally for a moment. Imagine a vast array of stations giving different information and angles on reality, but you only ever listen to one. Here we have the human plight in which the population is overwhelmingly confined to CultFM. This relates only to the frequency range of CultFM and limits perception and insight to that band – limits *possibility* to that band. It means you are connecting with an almost imperceptibly minuscule range of possibility and creative potential within the infinite Field. It's a world where everything seems apart from everything else and where synchronicity is rare. Synchronicity is defined in the dictionary as 'the happening by chance of two or more related or similar events at the same time'. Use of 'by chance' betrays a complete misunderstanding of reality. Synchronicity is not 'by chance'. As people open their minds, or 'awaken' to use the term, they notice more and more coincidences in their lives, bits of 'luck', apparently miraculous happenings that put them in the right place at the right time with the right people. Days become peppered with 'fancy meeting you here' and 'what are the chances of that?' My entire life has been lived like this and ever more so since my own colossal awakening in 1990 and 91 which transformed my sense of reality. Synchronicity is not 'by chance'; it is by accessing expanded

realms of possibility which allow expanded potential for manifestation. People broadcasting the same vibe from the same openness of mind tend to be drawn 'by chance' to each other through what I call frequency magnetism and it's not only people. In the last more than 30 years incredible synchronicity has also led me through the Cult maze to information in so many forms and to crucial personal experiences. These 'coincidences' have allowed me to put the puzzle pieces together across an enormous array of subjects and situations. Those who have breached the bubble of five-sense reality will know exactly what I mean and this escape from the perceptual prison cell is open to everyone whenever they make that choice. This may appear super-human when compared with the limitations of 'human', but it's really our natural state. 'Human' as currently experienced is consciousness in an unnatural state of induced separation from the infinity of the whole. I'll come to how this transformation into unity can be made when I have described in more detail the force that holds humanity in servitude by denying this access to infinite self.

The Wetiko factor

I have been talking and writing for decades about the way five-sense mind is systematically barricaded from expanded awareness. I have used the analogy of a computer (five-sense mind) and someone at the keyboard (expanded awareness). Interaction between the computer and the operator is symbolic of the interaction between five-sense mind and expanded awareness. The computer directly experiences the Internet and the operator experiences the Internet via the computer which is how it's supposed to be – the two working as one. Archons seek to control that point where the operator connects with the computer to stop that interaction (Fig 20). Now the operator is banging the keyboard and clicking the mouse, but the computer is not responding and this happens when the computer is taken over – *possessed* – by an appropriately-named computer 'virus'. The operator has lost all influence over the computer which goes its own way making decisions under the control of the 'virus'. I have

just described the dynamic through which the force known to Gnostics as Yaldabaoth and Archons disconnects five-sense mind from expanded awareness to imprison humanity in perceptual servitude.

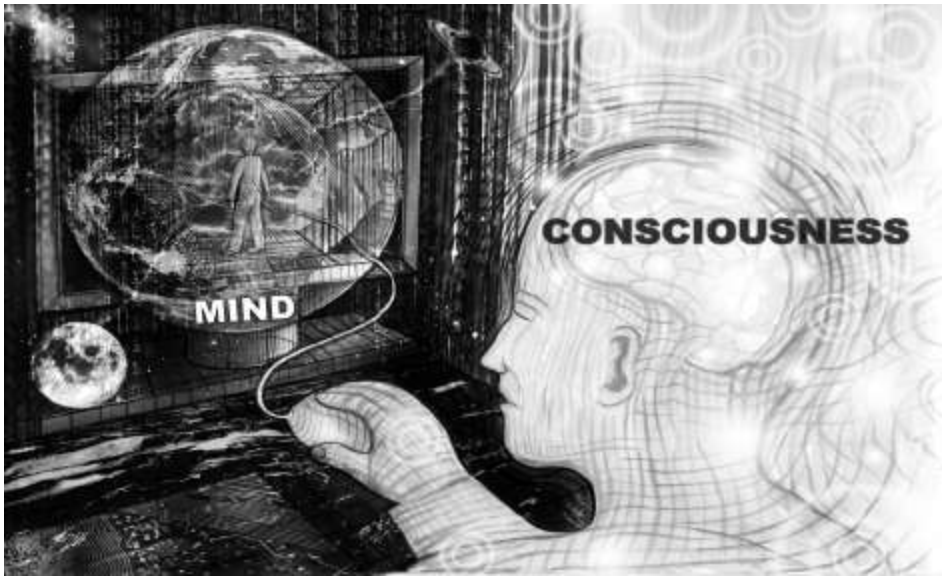


Figure 20: The mind 'virus' I have been writing about for decades seeks to isolate five-sense mind (the computer) from the true 'I'. (Image by Neil Hague).

About a year ago I came across a Native American concept of Wetiko which describes precisely the same phenomenon. Wetiko is the spelling used by the Cree and there are other versions including wintiko and windigo used by other tribal groups. They spell the name with lower case, but I see Wetiko as a proper noun as with Archons and prefer a capital. I first saw an article about Wetiko by writer and researcher Paul Levy which so synced with what I had been writing about the computer/operator disconnection and later the Archons. I then read his book, the fascinating *Dispelling Wetiko, Breaking the Spell of Evil*. The parallels between what I had concluded long before and the Native American concept of Wetiko were so clear and obvious that it was almost funny. For Wetiko see the Gnostic Archons for sure and the Jinn, the Predators, and every other name for a force of evil, inversion and chaos. Wetiko is the Native American name for the force that divides the computer from

the operator (Fig 21). Indigenous author Jack D. Forbes, a founder of the Native American movement in the 1960s, wrote another book about Wetiko entitled *Columbus And Other Cannibals – The Wetiko Disease of Exploitation, Imperialism, and Terrorism* which I also read. Forbes says that Wetiko refers to an evil person or spirit 'who terrorizes other creatures by means of terrible acts, including cannibalism'. Zulu shaman Credo Mutwa told me that African accounts tell how cannibalism was brought into the world by the Chitauri 'gods' – another manifestation of Wetiko. The distinction between 'evil person or spirit' relates to Archons/Wetiko possessing a human or acting as pure consciousness. Wetiko is said to be a sickness of the soul or spirit and a state of being that takes but gives nothing back – the Cult and its operatives perfectly described. Black Hawk, a Native American war leader defending their lands from confiscation, said European invaders had 'poisoned hearts' – Wetiko hearts – and that this would spread to native societies. Mention of the heart is very significant as we shall shortly see. Forbes writes: 'Tragically, the history of the world for the past 2,000 years is, in great part, the story of the epidemiology of the wetiko disease.' Yes, and much longer. Forbes is correct when he says: 'The wetikos destroyed Egypt and Babylon and Athens and Rome and Tenochtitlan [capital of the Aztec empire] and perhaps now they will destroy the entire earth.' Evil, he said, is the number one export of a Wetiko culture – see its globalisation with 'Covid'. Constant war, mass murder, suffering of all kinds, child abuse, Satanism, torture and human sacrifice are all expressions of Wetiko and the Wetiko possessed. The world is Wetiko made manifest, *but it doesn't have to be*. There is a way out of this even now.



Figure 21: The mind 'virus' is known to Native Americans as 'Wetiko'. (Image by Neil Hague).

Cult of Wetiko

Wetiko is the Yaldabaoth frequency distortion that seeks to attach to human consciousness and absorb it into its own. Once this connection is made Wetiko can drive the perceptions of the target which they believe to be coming from their own mind. All the horrors of history and today from mass killers to Satanists, paedophiles like Jeffrey Epstein and other psychopaths, are the embodiment of Wetiko and express its state of being in all its grotesqueness. The Cult is Wetiko incarnate, Yaldabaoth incarnate, and it seeks to facilitate Wetiko assimilation of humanity in totality into its distortion by manipulating the population into low frequency states that match its own. Paul Levy writes: 'Holographically enforced within the psyche of every human being the wetiko virus pervades and underlies the entire field of consciousness, and can therefore potentially manifest through any one of us at any moment if we are not mindful.' The 'Covid' hoax has achieved this with many people, but others have not fallen into Wetiko's frequency lair. Players in the 'Covid' human catastrophe including Gates, Schwab, Tedros, Fauci, Whitty, Vallance, Johnson, Hancock, Ferguson, Drosten, and all the rest, including the psychopath psychologists, are expressions of Wetiko. This is why

they have no compassion or empathy and no emotional consequence for what they do that would make them stop doing it. Observe all the people who support the psychopaths in authority against the Pushbackers despite the damaging impact the psychopaths have on their own lives and their family's lives. You are again looking at Wetiko possession which prevents them seeing through the lies to the obvious scam going on. *Why can't they see it?* Wetiko won't let them see it. The perceptual divide that has now become a chasm is between the Wetikoed and the non-Wetikoed.

Paul Levy describes Wetiko in the same way that I have long described the Archontic force. They are the same distorted consciousness operating across dimensions of reality: '… the subtle body of wetiko is not located in the third dimension of space and time, literally existing in another dimension … it is able to affect ordinary lives by mysteriously interpenetrating into our three-dimensional world.' Wetiko does this through its incarnate representatives in the Cult and by weaving itself into The Field which on our level of reality is the electromagnetic information field of the simulation or Matrix. More than that, the simulation *is* Wetiko / Yaldabaoth. Caleb Scharf, Director of Astrobiology at Columbia University, has speculated that 'alien life' could be so advanced that it has transcribed itself into the quantum realm to become what we call physics. He said intelligence indistinguishable from the fabric of the Universe would solve many of its greatest mysteries:

> Perhaps hyper-advanced life isn't just external. Perhaps it's already all around. It is embedded in what we perceive to be physics itself, from the root behaviour of particles and fields to the phenomena of complexity and emergence ... In other words, life might not just be in the equations. It might BE the equations [My emphasis].

Scharf said it is possible that 'we don't recognise advanced life because it forms an integral and unsuspicious part of what we've considered to be the natural world'. I agree. Wetiko/Yaldabaoth *is* the simulation. We are literally in the body of the beast. But that doesn't mean it has to control us. We all have the power to overcome Wetiko

influence and the Cult knows that. I doubt it sleeps too well because it knows that.

Which Field?

This, I suggest, is how it all works. There are two Fields. One is the fierce electromagnetic light of the Matrix within the speed of light; the other is the 'watery light' of The Field beyond the walls of the Matrix that connects with the Great Infinity. Five-sense mind and the decoding systems of the body attach us to the Field of Matrix light. They have to or we could not experience this reality. Five-sense mind sees only the Matrix Field of information while our expanded consciousness is part of the Infinity Field. When we open our minds, and most importantly our hearts, to the Infinity Field we have a mission control which gives us an expanded perspective, a road map, to understand the nature of the five-sense world. If we are isolated only in five-sense mind there is no mission control. We're on our own trying to understand a world that's constantly feeding us information to ensure we do not understand. People in this state can feel 'lost' and bewildered with no direction or radar. You can see ever more clearly those who are influenced by the Fields of Big Infinity or little five-sense mind simply by their views and behaviour with regard to the 'Covid' hoax. We have had this division throughout known human history with the mass of the people on one side and individuals who could see and intuit beyond the walls of the simulation – Plato's prisoner who broke out of the cave and saw reality for what it is. Such people have always been targeted by Wetiko/Archon-possessed authority, burned at the stake or demonised as mad, bad and dangerous. The Cult today and its global network of 'anti-hate', 'anti-fascist' Woke groups are all expressions of Wetiko attacking those exposing the conspiracy, 'Covid' lies and the 'vaccine' agenda.

Woke as a whole is Wetiko which explains its black and white mentality and how at one it is with the Wetiko-possessed Cult. Paul Levy said: 'To be in this paradigm is to still be under the thrall of a two-valued logic – where things are either true or false – of a

wetikoized mind.' Wetiko consciousness is in a permanent rage, therefore so is Woke, and then there is Woke inversion and contradiction. 'Anti-fascists' act like fascists because fascists *and* 'anti-fascists' are both Wetiko at work. Political parties act the same while claiming to be different for the same reason. Secret society and satanic rituals are attaching initiates to Wetiko and the cold, ruthless, psychopathic mentality that secures the positions of power all over the world is Wetiko. Reframing 'training programmes' have the same cumulative effect of attaching Wetiko and we have their graduates described as automatons and robots with a cold, psychopathic, uncaring demeanour. They are all traits of Wetiko possession and look how many times they have been described in this book and elsewhere with regard to personnel behind 'Covid' including the police and medical profession. Climbing the greasy pole in any profession in a Wetiko society requires traits of Wetiko to get there and that is particularly true of politics which is not about fair competition and pre-eminence of ideas. It is founded on how many backs you can stab and arses you can lick. This culminated in the global 'Covid' coordination between the Wetiko possessed who pulled it off in all the different countries without a trace of empathy and compassion for their impact on humans. Our sight sense can see only holographic form and not the Field which connects holographic form. Therefore we perceive 'physical' objects with 'space' in between. In fact that 'space' is energy/consciousness operating on multiple frequencies. One of them is Wetiko and that connects the Cult psychopaths, those who submit to the psychopaths, and those who serve the psychopaths in the media operations of the world. Wetiko is Gates. Wetiko is the mask-wearing submissive. Wetiko is the fake journalist and 'fact-checker'. The Wetiko Field is coordinating the whole thing. Psychopaths, gofers, media operatives, 'anti-hate' hate groups, 'fact-checkers' and submissive people work as one unit *even without human coordination* because they are attached to the *same* Field which is organising it all (Fig 22). Paul Levy is here describing how Wetiko-possessed people are drawn together and refuse to let any information breach their rigid

perceptions. He was writing long before ‘Covid’, but I think you will recognise followers of the ‘Covid’ religion *oh just a little bit*:

People who are channelling the vibratory frequency of wetiko align with each other through psychic resonance to reinforce their unspoken shared agreement so as to uphold their deranged view of reality. Once an unconscious content takes possession of certain individuals, it irresistibly draws them together by mutual attraction and knits them into groups tied together by their shared madness that can easily swell into an avalanche of insanity.

A psychic epidemic is a closed system, which is to say that it is insular and not open to any new information or informing influences from the outside world which contradict its fixed, limited, and limiting perspective.

There we have the Woke mind and the ‘Covid’ mind. Compatible resonance draws the awakening together, too, which is clearly happening today.



Figure 22: The Wetiko Field from which the Cult pyramid and its personnel are made manifest. (Image by Neil Hague).

Spiritual servitude

Wetiko doesn’t care about humans. It’s not human; it just possesses humans for its own ends and the effect (depending on the scale of

possession) can be anything from extreme psychopathy to unquestioning obedience. Wetiko's worst nightmare is for human consciousness to expand beyond the simulation. Everything is focussed on stopping that happening through control of information, thus perception, thus frequency. The 'education system', media, science, medicine, academia, are all geared to maintaining humanity in five-sense servitude as is the constant stimulation of low-vibrational mental and emotional states (see 'Covid'). Wetiko seeks to dominate those subconscious spaces between five-sense perception and expanded consciousness where the computer meets the operator. From these subconscious hiding places Wetiko speaks to us to trigger urges and desires that we take to be our own and manipulate us into anything from low-vibrational to psychopathic states. Remember how Islam describes the Jinn as invisible tricksters that 'whisper' and confuse. Wetiko is the origin of the 'trickster god' theme that you find in cultures all over the world. Jinn, like the Archons, are Wetiko which is terrified of humans awakening and reconnecting with our true self for then its energy source has gone. With that the feedback loop breaks between Wetiko and human perception that provides the energetic momentum on which its very existence depends as a force of evil. Humans are both its target and its source of survival, but only if we are operating in low-vibrational states of fear, hate, depression and the background anxiety that most people suffer. We are Wetiko's target because we are its key to survival. It needs us, not the other way round. Paul Levy writes:

A vampire has no intrinsic, independent, substantial existence in its own right; it only exists in relation to us. The pathogenic, vampiric mind-parasite called wetiko is nothing in itself – not being able to exist from its own side – yet it has a 'virtual reality' such that it can potentially destroy our species …

…The fact that a vampire is not reflected by a mirror can also mean that what we need to see is that there's nothing, no-thing to see, other than ourselves. The fact that wetiko is the expression of something inside of us means that the cure for wetiko is with us as well. The critical issue is finding this cure within us and then putting it into effect.

Evil begets evil because if evil does not constantly expand and find new sources of energetic sustenance its evil, its *distortion*, dies with the assimilation into balance and harmony. Love is the garlic to Wetiko's vampire. Evil, the absence of love, cannot exist in the presence of love. I think I see a way out of here. I have emphasised so many times over the decades that the Archons/Wetiko and their Cult are not all powerful. *They are not*. I don't care how it looks even now *they are not*. I have not called them little boys in short trousers for effect. I have said it because it is true. Wetiko's insatiable desire for power over others is not a sign of its omnipotence, but its insecurity. Paul Levy writes: 'Due to the primal fear which ultimately drives it and which it is driven to cultivate, wetiko's body politic has an intrinsic and insistent need for centralising power and control so as to create imagined safety for itself.' *Yeeeeeees!* Exactly! Why does Wetiko want humans in an ongoing state of fear? Wetiko itself *is* fear and it is petrified of love. As evil is an absence of love, so love is an absence of fear. Love conquers all and *especially* Wetiko which *is* fear. Wetiko brought fear into the world when it wasn't here before. *Fear* was the 'fall', the fall into low-frequency ignorance and illusion – fear is **F**alse **E**motion **A**ppearing **R**eal. The simulation is driven and energised by fear because Wetiko/Yaldabaoth (fear) *are* the simulation. Fear is the absence of love and Wetiko is the absence of love.

Wetiko today

We can now view current events from this level of perspective. The 'Covid' hoax has generated momentous amounts of ongoing fear, anxiety, depression and despair which have empowered Wetiko. No wonder people like Gates have been the instigators when they are Wetiko incarnate and exhibit every trait of Wetiko in the extreme. See how cold and unemotional these people are like Gates and his cronies, how dead of eye they are. That's Wetiko. Sabbatians are Wetiko and everything they control including the World Health Organization, Big Pharma and the 'vaccine' makers, national 'health'

hierarchies, corporate media, Silicon Valley, the banking system, and the United Nations with its planned transformation into world government. All are controlled and possessed by the Wetiko distortion into distorting human society in its image. We are with this knowledge at the gateway to understanding the world. Divisions of race, culture, creed and sexuality are diversions to hide the real division between those possessed and influenced by Wetiko and those that are not. The 'Covid' hoax has brought both clearly into view. Human behaviour is not about race. Tyrants and dictatorships come in all colours and creeds. What unites the US president bombing the innocent and an African tribe committing genocide against another as in Rwanda? What unites them? *Wetiko*. All wars are Wetiko, all genocide is Wetiko, all hunger over centuries in a world of plenty is Wetiko. Children going to bed hungry, including in the West, is Wetiko. Cult-generated Woke racial divisions that focus on the body are designed to obscure the reality that divisions in behaviour are manifestations of mind, not body. Obsession with body identity and group judgement is a means to divert attention from the real source of behaviour – mind and perception. Conflict sown by the Woke both within themselves and with their target groups are Wetiko providing lunch for itself through still more agents of the division, chaos, and fear on which it feeds. The Cult is seeking to assimilate the entirety of humanity and all children and young people into the Wetiko frequency by manipulating them into states of fear and despair. Witness all the suicide and psychological unravelling since the spring of 2020. Wetiko psychopaths want to impose a state of unquestioning obedience to authority which is no more than a conduit for Wetiko to enforce its will and assimilate humanity into itself. It needs us to believe that resistance is futile when it fears resistance and even more so the game-changing non-cooperation with its impositions. It can use violent resistance for its benefit. Violent impositions and violent resistance are *both* Wetiko. The Power of Love with its Power of No will sweep Wetiko from our world. Wetiko and its Cult know that. They just don't want us to know.

AI Wetiko

This brings me to AI or artificial intelligence and something else Wetikos don't want us to know. What is AI *really*? I know about computer code algorithms and AI that learns from data input. These, however, are more diversions, the expeditionary force, for the real AI that they want to connect to the human brain as promoted by Silicon Valley Wetikos like Kurzweil. What is this AI? It is the frequency of *Wetiko*, the frequency of the Archons. The connection of AI to the human brain is the connection of the Wetiko frequency to create a Wetiko hive mind and complete the job of assimilation. The hive mind is planned to be controlled from Israel and China which are both 100 percent owned by Wetiko Sabbatians. The assimilation process has been going on minute by minute in the 'smart' era which fused with the 'Covid' era. We are told that social media is scrambling the minds of the young and changing their personality. This is true, but what is social media? Look more deeply at how it works, how it creates divisions and conflict, the hostility and cruelty, the targeting of people until they are destroyed. That's Wetiko. Social media is manipulated to tune people to the Wetiko frequency with all the emotional exploitation tricks employed by platforms like Facebook and its Wetiko front man, Zuckerberg. Facebook's Instagram announced a new platform for children to overcome a legal bar on them using the main site. This is more Wetiko exploitation and manipulation of kids. Amnesty International likened the plan to foxes offering to guard the henhouse and said it was incompatible with human rights. Since when did Wetiko or Zuckerberg (I repeat myself) care about that? Would Brin and Page at Google, Wojcicki at YouTube, Bezos at Amazon and whoever the hell runs Twitter act as they do if they were not channelling Wetiko? Would those who are developing technologies for no other reason than human control? How about those designing and selling technologies to kill people and Big Pharma drug and 'vaccine' producers who know they will end or devastate lives? Quite a thought for these people to consider is that if you are Wetiko in a human life you are Wetiko on the 'other side' unless your frequency

changes and that can only change by a change of perception which becomes a change of behaviour. Where Gates is going does not bear thinking about although perhaps that's exactly where he wants to go. Either way, that's where he's going. His frequency will make it so.

The frequency lair

I have been saying for a long time that a big part of the addiction to smartphones and devices is that a frequency is coming off them that entraps the mind. People spend ages on their phones and sometimes even a minute or so after they put them down they pick them up again and it all repeats. 'Covid' lockdowns will have increased this addiction a million times for obvious reasons. Addictions to alcohol overindulgence and drugs are another way that Wetiko entraps consciousness to attach to its own. Both are symptoms of low-vibrational psychological distress which alcoholism and drug addiction further compound. Do we think it's really a coincidence that access to them is made so easy while potions that can take people into realms beyond the simulation are banned and illegal? I have explored smartphone addiction in other books, the scale is mind-blowing, and that level of addiction does not come without help. Tech companies that make these phones are Wetiko and they will have no qualms about destroying the minds of children. We are seeing again with these companies the Wetiko perceptual combination of psychopathic enforcers and weak and meek unquestioning compliance by the rank and file.

The global Smart Grid is the Wetiko Grid and it is crucial to complete the Cult endgame. The simulation is radiation and we are being deluged with technological radiation on a devastating scale. Wetiko frauds like Elon Musk serve Cult interests while occasionally criticising them to maintain his street-cred. 5G and other forms of Wi-Fi are being directed at the earth from space on a volume and scale that goes on increasing by the day. Elon Musk's (officially) SpaceX Starlink project is in the process of putting tens of thousands of satellites in low orbit to cover every inch of the planet with 5G and other Wi-Fi to create Kurzweil's global 'cloud' to which the

human mind is planned to be attached very soon. SpaceX has approval to operate 12,000 satellites with more than 1,300 launched at the time of writing and applications filed for *30,000* more. Other operators in the Wi-Fi, 5G, low-orbit satellite market include OneWeb (UK), Telesat (Canada), and AST & Science (US). Musk tells us that AI could be the end of humanity and then launches a company called Neuralink to connect the human brain to computers. Musk's (in theory) Tesla company is building electric cars and the driverless vehicles of the smart control grid. As frauds and bullshitters go Elon Musk in my opinion is Major League.

5G and technological radiation in general are destructive to human health, genetics and psychology and increasing the strength of artificial radiation underpins the five-sense perceptual bubbles which are themselves expressions of radiation or electromagnetism. Freedom activist John Whitehead was so right with his 'databit by databit, we are building our own electronic concentration camps'. The Smart Grid and 5G is a means to control the human mind and infuse perceptual information into The Field to influence anyone in sync with its frequency. You can change perception and behaviour en masse if you can manipulate the population into those levels of frequency and this is happening all around us today. The arrogance of Musk and his fellow Cult operatives knows no bounds in the way that we see with Gates. Musk's satellites are so many in number already they are changing the night sky when viewed from Earth. The astronomy community has complained about this and they have seen nothing yet. Some consequences of Musk's Wetiko hubris include: Radiation; visible pollution of the night sky; interference with astronomy and meteorology; ground and water pollution from intensive use of increasingly many spaceports; accumulating space debris; continual deorbiting and burning up of aging satellites, polluting the atmosphere with toxic dust and smoke; and ever-increasing likelihood of collisions. A collective public open letter of complaint to Musk said:

> We are writing to you … because SpaceX is in process of surrounding the Earth with a network of thousands of satellites whose very purpose is to irradiate every square inch of the

Earth. SpaceX, like everyone else, is treating the radiation as if it were not there. As if the mitochondria in our cells do not depend on electrons moving undisturbed from the food we digest to the oxygen we breathe.

As if our nervous systems and our hearts are not subject to radio frequency interference like any piece of electronic equipment. As if the cancer, diabetes, and heart disease that now afflict a majority of the Earth's population are not metabolic diseases that result from interference with our cellular machinery. As if insects everywhere, and the birds and animals that eat them, are not starving to death as a result.

People like Musk and Gates believe in their limitless Wetiko arrogance that they can do whatever they like to the world because they own it. Consequences for humanity are irrelevant. It's absolutely time that we stopped taking this shit from these self-styled masters of the Earth when you consider where this is going.

Why is the Cult so anti-human?

I hear this question often: Why would they do this when it will affect them, too? Ah, but will it? Who is this *them*? Forget their bodies. They are just vehicles for Wetiko consciousness. When you break it all down to the foundations we are looking at a state of severely distorted consciousness targeting another state of consciousness for assimilation. The rest is detail. The simulation is the fly-trap in which unique sensations of the five senses create a cycle of addiction called reincarnation. Renegade Minds see that everything which happens in our reality is a smaller version of the whole picture in line with the holographic principle. Addiction to the radiation of smart technology is a smaller version of addiction to the whole simulation. Connecting the body/brain to AI is taking that addiction on a giant step further to total ongoing control by assimilating human incarnate consciousness into Wetiko. I have watched during the 'Covid' hoax how many are becoming ever more profoundly attached to Wetiko's perceptual calling cards of aggressive response to any other point of view ('There is no other god but me'), psychopathic lack of compassion and empathy, and servile submission to the narrative and will of authority. Wetiko is the psychopaths *and* subservience to psychopaths. The Cult of Wetiko is

so anti-human because it is *not* human. It embarked on a mission to destroy human by targeting everything that it means to be human and to survive as human. 'Covid' is not the end, just a means to an end. The Cult with its Wetiko consciousness is seeking to change Earth systems, including the atmosphere, to suit them, not humans. The gathering bombardment of 5G alone from ground and space is dramatically changing The Field with which the five senses interact. There is so much more to come if we sit on our hands and hope it will all go away. It is not meant to go away. It is meant to get ever more extreme and we need to face that while we still can – just.

Carbon dioxide is the gas of life. Without that human is over. Kaput, gone, history. No natural world, no human. The Cult has created a cock and bull story about carbon dioxide and climate change to justify its reduction to the point where Gates and the ignoramus Biden 'climate chief' John Kerry want to suck it out of the atmosphere. Kerry wants to do this because his master Gates does. Wetikos have made the gas of life a demon with the usual support from the Wokers of Extinction Rebellion and similar organisations and the bewildered puppet-child that is Greta Thunberg who was put on the world stage by Klaus Schwab and the World Economic Forum. The name Extinction Rebellion is both ironic and as always Wetiko inversion. The gas that we need to survive must be reduced to save us from extinction. The most basic need of human is oxygen and we now have billions walking around in face nappies depriving body and brain of this essential requirement of human existence. More than that 5G at 60 gigahertz interacts with the oxygen molecule to reduce the amount of oxygen the body can absorb into the bloodstream. The obvious knock-on consequences of that for respiratory and cognitive problems and life itself need no further explanation. Psychopaths like Musk are assembling a global system of satellites to deluge the human atmosphere with this insanity. The man should be in jail. Here we have two most basic of human needs, oxygen and carbon dioxide, being dismantled.

Two others, water and food, are getting similar treatment with the United Nations Agendas 21 and 2030 – the Great Reset – planning to

centrally control all water and food supplies. People will not even own rain water that falls on their land. Food is affected at the most basic level by reducing carbon dioxide. We have genetic modification or GMO infiltrating the food chain on a mass scale, pesticides and herbicides polluting the air and destroying the soil. Freshwater fish that provide livelihoods for 60 million people and feed hundreds of millions worldwide are being 'pushed to the brink' according the conservationists while climate change is the only focus. Now we have Gates and Schwab wanting to dispense with current food sources all together and replace them with a synthetic version which the Wetiko Cult would control in terms of production and who eats and who doesn't. We have been on the Totalitarian Tiptoe to this for more than 60 years as food has become ever more processed and full of chemical shite to the point today when it's not natural food at all. As Dr Tom Cowan says: 'If it has a label don't eat it.' Bill Gates is now the biggest owner of farmland in the United States and he does nothing without an ulterior motive involving the Cult. Klaus Schwab wrote: 'To feed the world in the next 50 years we will need to produce as much food as was produced in the last 10,000 years … food security will only be achieved, however, if regulations on genetically modified foods are adapted to reflect the reality that gene editing offers a precise, efficient and safe method of improving crops.' Liar. People and the world are being targeted with aluminium through vaccines, chemtrails, food, drink cans, and endless other sources when aluminium has been linked to many health issues including dementia which is increasing year after year. Insects, bees and wildlife essential to the food chain are being deleted by pesticides, herbicides and radiation which 5G is dramatically increasing with 6G and 7G to come. The pollinating bee population is being devastated while wildlife including birds, dolphins and whales are having their natural radar blocked by the effects of ever-increasing radiation. In the summer windscreens used to be splattered with insects so numerous were they. It doesn't happen now. Where have they gone?

Synthetic everything

The Cult is introducing genetically-modified versions of trees, plants and insects including a Gates-funded project to unleash hundreds of millions of genetically-modified, lab-altered and patented male mosquitoes to mate with wild mosquitoes and induce genetic flaws that cause them to die out. Clinically-insane Gates-funded Japanese researchers have developed mosquitos that spread vaccine and are dubbed 'flying vaccinators'. Gates is funding the modification of weather patterns in part to sell the myth that this is caused by carbon dioxide and he's funding geoengineering of the skies to change the atmosphere. Some of this came to light with the Gates-backed plan to release tonnes of chalk into the atmosphere to 'deflect the Sun and cool the planet'. Funny how they do this while the heating effect of the Sun is not factored into climate projections focussed on carbon dioxide. The reason is that they want to reduce carbon dioxide (so don't mention the Sun), but at the same time they do want to reduce the impact of the Sun which is so essential to human life and health. I have mentioned the sun-cholesterol-vitamin D connection as they demonise the Sun with warnings about skin cancer (caused by the chemicals in sun cream they tell you to splash on). They come from the other end of the process with statin drugs to reduce cholesterol that turns sunlight into vitamin D. A lack of vitamin D leads to a long list of health effects and how vitamin D levels must have fallen with people confined to their homes over 'Covid'. Gates is funding other forms of geoengineering and most importantly chemtrails which are dropping heavy metals, aluminium and self-replicating nanotechnology onto the Earth which is killing the natural world. See *Everything You Need To Know, But Have Never Been Told* for the detailed background to this.

Every human system is being targeted for deletion by a force that's not human. The Wetiko Cult has embarked on the process of transforming the human body from biological to synthetic biological as I have explained. Biological is being replaced by the artificial and synthetic – Archontic 'countermimicry' – right across human society. The plan eventually is to dispense with the human body altogether

and absorb human consciousness – which it wouldn't really be by then – into cyberspace (the simulation which is Wetiko/Yaldabaoth). Preparations for that are already happening if people would care to look. The alternative media rightly warns about globalism and 'the globalists', but this is far bigger than that and represents the end of the human race as we know it. The 'bad copy' of prime reality that Gnostics describe was a bad copy of harmony, wonder and beauty to start with before Wetiko/Yaldabaoth set out to change the simulated 'copy' into something very different. The process was slow to start with. Entrapped humans in the simulation timeline were not technologically aware and they had to be brought up to intellectual speed while being suppressed spiritually to the point where they could build their own prison while having no idea they were doing so. We have now reached that stage where technological intellect has the potential to destroy us and that's why events are moving so fast. Central American shaman Don Juan Matus said:

> Think for a moment, and tell me how you would explain the contradictions between the intelligence of man the engineer and the stupidity of his systems of belief, or the stupidity of his contradictory behaviour. Sorcerers believe that the predators have given us our systems of beliefs, our ideas of good and evil; our social mores. They are the ones who set up our dreams of success or failure. They have given us covetousness, greed, and cowardice. It is the predator who makes us complacent, routinary, and egomaniacal.
>
> In order to keep us obedient and meek and weak, the predators engaged themselves in a stupendous manoeuvre – stupendous, of course, from the point of view of a fighting strategist; a horrendous manoeuvre from the point of those who suffer it. They gave us their mind. The predators' mind is baroque, contradictory, morose, filled with the fear of being discovered any minute now.

For 'predators' see Wetiko, Archons, Yaldabaoth, Jinn, and all the other versions of the same phenomenon in cultures and religions all over the world. The theme is always the same because it's true and it's real. We have reached the point where we have to deal with it. The question is – how?

Don't fight – walk away

I thought I'd use a controversial subheading to get things moving in terms of our response to global fascism. What do you mean 'don't fight'? What do you mean 'walk away'? We've got to fight. We can't walk away. Well, it depends what we mean by fight and walk away. If fighting means physical combat we are playing Wetiko's game and falling for its trap. It wants us to get angry, aggressive, and direct hate and hostility at the enemy we think we must fight. Every war, every battle, every conflict, has been fought with Wetiko leading both sides. It's what it does. Wetiko wants a fight, anywhere, any place. Just hit me, son, so I can hit you back. Wetiko hits Wetiko and Wetiko hits Wetiko in return. I am very forthright as you can see in exposing Wetikos of the Cult, but I don't hate them. I refuse to hate them. It's what they want. What you hate you become. What you *fight* you become. Wokers, 'anti-haters' and 'anti-fascists' prove this every time they reach for their keyboards or don their balaclavas. By walk away I mean to disengage from Wetiko which includes ceasing to cooperate with its tyranny. Paul Levy says of Wetiko:

> The way to 'defeat' evil is not to try to destroy it (for then, in playing evil's game, we have already lost), but rather, to find the invulnerable place within ourselves where evil is unable to vanquish us – this is to truly 'win' our battle with evil.

Wetiko is everywhere in human society and it's been on steroids since the 'Covid' hoax. Every shouting match over wearing masks has Wetiko wearing a mask and Wetiko not wearing one. It's an electrical circuit of push and resist, push and resist, with Wetiko pushing *and* resisting. Each polarity is Wetiko empowering itself. Dictionary definitions of 'resist' include 'opposing, refusing to accept or comply with' and the word to focus on is 'opposing'. What form does this take – setting police cars alight or 'refusing to accept or comply with'? The former is Wetiko opposing Wetiko while the other points the way forward. This is the difference between those aggressively demanding that government fascism must be obeyed who stand in stark contrast to the great majority of Pushbackers. We saw this clearly with a march by thousands of Pushbackers against lockdown in London followed days later by a Woker-hijacked

protest in Bristol in which police cars were set on fire. Masks were virtually absent in London and widespread in Bristol. Wetiko wants lockdown on every level of society and infuses its aggression to police it through its unknowing stooges. Lockdown protesters are the ones with the smiling faces and the hugs, The two blatantly obvious states of being – getting more obvious by the day – are the result of Wokers and their like becoming ever more influenced by the simulation Field of Wetiko and Pushbackers ever more influenced by The Field of a far higher vibration beyond the simulation. Wetiko can't invade the heart which is where most lockdown opponents are coming from. It's the heart that allows them to see through the lies to the truth in ways I will be highlighting.

Renegade Minds know that calmness is the place from which wisdom comes. You won't find wisdom in a hissing fit and wisdom is what we need in abundance right now. Calmness is not weakness – you don't have to scream at the top of your voice to be strong. Calmness is indeed a sign of strength. 'No' means I'm not doing it. *NOOOO!!!* doesn't mean you're not doing it even more. Volume does not advance 'No – I'm not doing it'. You are just not doing it. Wetiko possessed and influenced don't know how to deal with that. Wetiko wants a fight and we should not give it one. What it needs more than anything is our *cooperation* and we should not give that either. Mass rallies and marches are great in that they are a visual representation of feeling, but if it ends there they are irrelevant. You demand that Wetikos act differently? Well, they're not going to are they? They are Wetikos. We don't need to waste our time demanding that something doesn't happen when that will make no difference. We need to delete the means that *allows* it to happen. This, invariably, is our cooperation. You can demand a child stop firing a peashooter at the dog or you can refuse to buy the peashooter. If you provide the means you are cooperating with the dog being smacked on the nose with a pea. How can the authorities enforce mask-wearing if millions in a country refuse? What if the 74 million Pushbackers that voted for Trump in 2020 refused to wear masks, close their businesses or stay in their homes. It would be unenforceable. The

few control the many through the compliance of the many and that's always been the dynamic be it 'Covid' regulations or the Roman Empire. I know people can find it intimidating to say no to authority or stand out in a crowd for being the only one with a face on display; but it has to be done or it's over. I hope I've made clear in this book that where this is going will be far more intimidating than standing up now and saying 'No' – I will not cooperate with my own enslavement and that of my children. There might be consequences for some initially, although not so if enough do the same. The question that must be addressed is what is going to happen if we don't? It is time to be strong and unyieldingly so. No means no. Not here and there, but *everywhere* and *always*. I have refused to wear a mask and obey all the other nonsense. I will not comply with tyranny. I repeat: Fascism is not imposed by fascists – there are never enough of them. Fascism is imposed by the population acquiescing to fascism. *I will not do it*. I will die first, or my body will. Living meekly under fascism is a form of death anyway, the death of the spirit that Martin Luther King described.

Making things happen

We must not despair. This is not over till it's over and it's far from that. The 'fat lady' must refuse to sing. The longer the 'Covid' hoax has dragged on and impacted on more lives we have seen an awakening of phenomenal numbers of people worldwide to the realisation that what they have believed all their lives is not how the world really is. Research published by the system-serving University of Bristol and King's College London in February, 2021, concluded: 'One in every 11 people in Britain say they trust David Icke's take on the coronavirus pandemic.' It will be more by now and we have gathering numbers to build on. We must urgently progress from seeing the scam to ceasing to cooperate with it. Prominent German lawyer Reiner Fuellmich, also licenced to practice law in America, is doing a magnificent job taking the legal route to bring the psychopaths to justice through a second Nuremberg tribunal for crimes against humanity. Fuellmich has an impressive record of

beating the elite in court and he formed the German Corona Investigative Committee to pursue civil charges against the main perpetrators with a view to triggering criminal charges. Most importantly he has grasped the foundation of the hoax – the PCR test not testing for the 'virus' – and Christian Drosten is therefore on his charge sheet along with Gates frontman Tedros at the World Health Organization. Major players must be not be allowed to inflict their horrors on the human race without being brought to book. A life sentence must follow for Bill Gates and the rest of them. A group of researchers has also indicted the government of Norway for crimes against humanity with copies sent to the police and the International Criminal Court. The lawsuit cites participation in an internationally-planned false pandemic and violation of international law and human rights, the European Commission's definition of human rights by coercive rules, Nuremberg and Hague rules on fundamental human rights, and the Norwegian constitution. We must take the initiative from hereon and not just complain, protest and react.

There are practical ways to support vital mass non-cooperation. Organising in numbers is one. Lockdown marches in London in the spring in 2021 were mass non-cooperation that the authorities could not stop. There were too many people. Hundreds of thousands walked the London streets in the centre of the road for mile after mile while the Face-Nappies could only look on. They were determined, but calm, and just *did it* with no histrionics and lots of smiles. The police were impotent. Others are organising group shopping without masks for mutual support and imagine if that was happening all over. Policing it would be impossible. If the store refuses to serve people in these circumstances they would be faced with a long line of trolleys full of goods standing on their own and everything would have to be returned to the shelves. How would they cope with that if it kept happening? I am talking here about moving on from complaining to being pro-active; from watching things happen to making things happen. I include in this our relationship with the police. The behaviour of many Face-Nappies

has been disgraceful and anyone who thinks they would never find concentration camp guards in the 'enlightened' modern era have had that myth busted big-time. The period and setting may change – Wetikos never do. I watched film footage from a London march in which a police thug viciously kicked a protestor on the floor who had done nothing. His fellow Face-Nappies stood in a ring protecting him. What he did was a criminal assault and with a crowd far outnumbering the police this can no longer be allowed to happen unchallenged. I get it when people chant 'shame on you' in these circumstances, but that is no longer enough. They *have* no shame those who do this. Crowds needs to start making a citizen's arrest of the police who commit criminal offences and brutally attack innocent people and defenceless women. A citizen's arrest can be made under section 24A of the UK Police and Criminal Evidence (PACE) Act of 1984 and you will find something similar in other countries. I prefer to call it a Common Law arrest rather than citizen's for reasons I will come to shortly. Anyone can arrest a person committing an indictable offence or if they have reasonable grounds to suspect they are committing an indictable offence. On both counts the attack by the police thug would have fallen into this category. A citizen's arrest can be made to stop someone:

- Causing physical injury to himself or any other person
- Suffering physical injury
- Causing loss of or damage to property
- Making off before a constable can assume responsibility for him

A citizen's arrest may also be made to prevent a breach of the peace under Common Law and if they believe a breach of the peace will happen or anything related to harm likely to be done or already done in their presence. This is the way to go I think – the Common Law version. If police know that the crowd and members of the public will no longer be standing and watching while they commit

their thuggery and crimes they will think twice about acting like Brownshirts and Blackshirts.

Common Law – common sense

Mention of Common Law is very important. Most people think the law is the law as in one law. This is not the case. There are two bodies of law, Common Law and Statute Law, and they are not the same. Common Law is founded on the simple premise of do no harm. It does not recognise victimless crimes in which no harm is done while Statute Law does. There is a Statute Law against almost everything. So what is Statute Law? Amazingly it's the law of the *sea* that was brought ashore by the Cult to override the law of the land which is Common Law. They had no right to do this and as always they did it anyway. They had to. They could not impose their will on the people through Common Law which only applies to do no harm. How could you stitch up the fine detail of people's lives with that? Instead they took the law of the sea, or Admiralty Law, and applied it to the population. Statute Law refers to all the laws spewing out of governments and their agencies including all the fascist laws and regulations relating to 'Covid'. The key point to make is that Statute Law is *contract law*. It only applies between *contracting* corporations. Most police officers don't even know this. They have to be kept in the dark, too. Long ago when merchants and their sailing ships began to trade with different countries a contractual law was developed called Admiralty Law and other names. Again it only applied to *contracts* agreed between *corporate* entities. If there is no agreed contract the law of the sea had no jurisdiction *and that still applies to its new alias of Statute Law*. The problem for the Cult when the law of the sea was brought ashore was an obvious one. People were not corporations and neither were government entities. To overcome the latter they made governments and all associated organisations corporations. All the institutions are *private corporations* and I mean governments and their agencies, local councils, police, courts, military, US states, the whole lot. Go to the

Dun and Bradstreet corporate listings website for confirmation that they are all corporations. You are arrested by a private corporation called the police by someone who is really a private security guard and they take you to court which is another private corporation. Neither have jurisdiction over you unless you consent and *contract* with them. This is why you hear the mantra about law enforcement policing by *consent* of the people. In truth the people 'consent' only in theory through monumental trickery.

Okay, the Cult overcame the corporate law problem by making governments and institutions corporate entities; but what about people? They are not corporations are they? Ah ... well in a sense, and *only* a sense, they are. Not people exactly – the illusion of people. The Cult creates a corporation in the name of everyone at the time that their birth certificate is issued. Note birth/ *berth* certificate and when you go to court under the law of the sea on land you stand in a *dock*. These are throwbacks to the origin. My Common Law name is David Vaughan Icke. The name of the corporation created by the government when I was born is called Mr David Vaughan Icke usually written in capitals as MR DAVID VAUGHAN ICKE. That is not me, the living, breathing man. It is a fictitious corporate entity. The trick is to make you think that David Vaughan Icke and MR DAVID VAUGHAN ICKE are the same thing. *They are not*. When police charge you and take you to court they are prosecuting the corporate entity and not the living, breathing, man or woman. They have to trick you into identifying as the corporate entity and contracting with them. Otherwise they have no jurisdiction. They do this through a language known as legalese. Lawful and legal are not the same either. Lawful relates to Common Law and legal relates to Statute Law. Legalese is the language of Statue Law which uses terms that mean one thing to the public and another in legalese. Notice that when a police officer tells someone why they are being charged he or she will say at the end: 'Do you understand?' To the public that means 'Do you comprehend?' In legalese it means 'Do you stand under me?' Do you stand under my authority? If you say

yes to the question you are unknowingly agreeing to give them jurisdiction over you in a contract between two corporate entities.

This is a confidence trick in every way. Contracts have to be agreed between informed parties and if you don't know that David Vaughan Icke is agreeing to be the corporation MR DAVID VAUGHAN ICKE you cannot knowingly agree to contract. They are deceiving you and another way they do this is to ask for proof of identity. You usually show them a driving licence or other document on which your corporate name is written. In doing so you are accepting that you are that corporate entity when you are not. Referring to yourself as a 'person' or 'citizen' is also identifying with your corporate fiction which is why I made the Common Law point about the citizen's arrest. If you are approached by a police officer you identify yourself immediately as a living, breathing, man or woman and say 'I do not consent, I do not contract with you and I do not understand' or stand under their authority. I have a Common Law birth certificate as a living man and these are available at no charge from commonlawcourt.com. Businesses registered under the Statute Law system means that its laws apply. There are, however, ways to run a business under Common Law. Remember all 'Covid' laws and regulations are Statute Law – the law of *contracts* and you do not have to contract. This doesn't mean that you can kill someone and get away with it. Common Law says do no harm and that applies to physical harm, financial harm etc. Police are employees of private corporations and there needs to be a new system of non-corporate Common Law constables operating outside the Statute Law system. If you go to davidicke.com and put Common Law into the search engine you will find videos that explain Common Law in much greater detail. It is definitely a road we should walk.

With all my heart

I have heard people say that we are in a spiritual war. I don't like the term 'war' with its Wetiko dynamic, but I know what they mean. Sweep aside all the bodily forms and we are in a situation in which two states of consciousness are seeking very different realities.

Wetiko wants upheaval, chaos, fear, suffering, conflict and control. The other wants love, peace, harmony, fairness and freedom. That's where we are. We should not fall for the idea that Wetiko is all-powerful and there's nothing we can do. Wetiko is not all-powerful. It's a joke, pathetic. It doesn't have to be, but it has made that choice for now. A handful of times over the years when I have felt the presence of its frequency I have allowed it to attach briefly so I could consciously observe its nature. The experience is not pleasant, the energy is heavy and dark, but the ease with which you can kick it back out the door shows that its real power is in persuading us that it has power. It's all a con. Wetiko is a con. It's a trickster and not a power that can control us if we unleash our own. The con is founded on manipulating humanity to give its power to Wetiko which recycles it back to present the illusion that it has power when its power is *ours* that we gave away. This happens on an energetic level and plays out in the world of the seen as humanity giving its power to Wetiko authority which uses that power to control the population when the power is only the power the population has handed over. How could it be any other way for billions to be controlled by a relative few? I have had experiences with people possessed by Wetiko and again you can kick its arse if you do it with an open heart. Oh yes – the *heart* which can transform the world of perceived 'matter'.

We are receiver-transmitters and processors of information, but what information and where from? Information is processed into perception in three main areas – the brain, the heart and the belly. These relate to thinking, knowing, and emotion. Wetiko wants us to be head and belly people which means we think within the confines of the Matrix simulation and low-vibrational emotional reaction scrambles balance and perception. A few minutes on social media and you see how emotion is the dominant force. Woke is all emotion and is therefore thought-free and fact-free. Our heart is something different. It *knows* while the head *thinks* and has to try to work it out because it doesn't know. The human energy field has seven prime vortexes which connect us with wider reality (Fig 23). Chakra means

'wheels of light' in the Sanskrit language of ancient India. The main ones are: The crown chakra on top of the head; brow (or 'third eye') chakra in the centre of the forehead; throat chakra; heart chakra in the centre of the chest; solar plexus chakra below the sternum; sacral chakra beneath the navel; and base chakra at the bottom of the spine. Each one has a particular function or functions. We feel anxiety and nervousness in the belly where the sacral chakra is located and this processes emotion that can affect the colon to give people 'the shits' or make them 'shit scared' when they are nervous. Chakras all play an important role, but the Mr and Mrs Big is the heart chakra which sits at the centre of the seven, above the chakras that connect us to the 'physical' and below those that connect with higher realms (or at least should). Here in the heart chakra we feel love, empathy and compassion – 'My heart goes out to you'. Those with closed hearts become literally 'heart-less' in their attitudes and behaviour (see Bill Gates). Native Americans portrayed Wetiko with what Paul Levy calls a 'frigid, icy heart, devoid of mercy' (see Bill Gates).



Figure 23: The chakra system which interpenetrates the human energy field. The heart chakra is the governor – or should be.

Wetiko trembles at the thought of heart energy which it cannot infiltrate. The frequency is too high. What it seeks to do instead is close the heart chakra vortex to block its perceptual and energetic influence. Psychopaths have 'hearts of stone' and emotionally-damaged people have 'heartache' and 'broken hearts'. The astonishing amount of heart disease is related to heart chakra

disruption with its fundamental connection to the 'physical' heart. Dr Tom Cowan has written an outstanding book challenging the belief that the heart is a pump and making the connection between the 'physical' and spiritual heart. Rudolph Steiner who was way ahead of his time said the same about the fallacy that the heart is a pump. *What*? The heart is not a pump? That's crazy, right? Everybody knows that. Read Cowan's *Human Heart, Cosmic Heart* and you will realise that the very idea of the heart as a pump is ridiculous when you see the evidence. How does blood in the feet so far from the heart get pumped horizontally up the body by the heart?? Cowan explains in the book the real reason why blood moves as it does. Our 'physical' heart is used to symbolise love when the source is really the heart vortex or spiritual heart which is our most powerful energetic connection to 'out there' expanded consciousness. That's why we feel *knowing* – intuitive knowing – in the centre of the chest. Knowing doesn't come from a process of thoughts leading to a conclusion. It is there in an instant all in one go. Our heart knows because of its connection to levels of awareness that *do* know. This is the meaning and source of intuition – intuitive *knowing*.

For the last more than 30 years of uncovering the global game and the nature of reality my heart has been my constant antenna for truth and accuracy. An American intelligence insider once said that I had quoted a disinformer in one of my books and yet I had only quoted the part that was true. He asked: 'How do you do that?' By using my heart antenna was the answer and anyone can do it. Heart-centred is how we are meant to be. With a closed heart chakra we withdraw into a closed mind and the bubble of five-sense reality. If you take a moment to focus your attention on the centre of your chest, picture a spinning wheel of light and see it opening and expanding. You will feel it happening, too, and perceptions of the heart like joy and love as the heart impacts on the mind as they interact. The more the chakra opens the more you will feel expressions of heart consciousness and as the process continues, and becomes part of you, insights and knowings will follow. An open

heart is connected to that level of awareness that knows all is *One*. You will see from its perspective that the fault-lines that divide us are only illusions to control us. An open heart does not process the illusions of race, creed and sexuality except as brief experiences for a consciousness that is all. Our heart does not see division, only unity (Figs 24 and 25). There's something else, too. Our hearts love to laugh. Mark Twain's quote that says 'The human race has one really effective weapon, and that is laughter' is really a reference to the heart which loves to laugh with the joy of knowing the true nature of infinite reality and that all the madness of human society is an illusion of the mind. Twain also said: 'Against the assault of laughter nothing can stand.' This is so true of Wetiko and the Cult. Their insecurity demands that they be taken seriously and their power and authority acknowledged and feared. We should do nothing of the sort. We should not get aggressive or fearful which their insecurity so desires. We should laugh in their face. Even in their no-face as police come over in their face-nappies and expect to be taken seriously. They don't take themselves seriously looking like that so why should we? Laugh in the face of intimidation. Laugh in the face of tyranny. You will see by its reaction that you have pressed all of its buttons. Wetiko does not know what to do in the face of laughter or when its targets refuse to concede their joy to fear. We have seen many examples during the 'Covid' hoax when people have expressed their energetic power and the string puppets of Wetiko retreat with their tail limp between their knees. Laugh – the world is bloody mad after all and if it's a choice between laughter and tears I know which way I'm going.



Figure 24: Head consciousness without the heart sees division and everything apart from everything else.



Figure 25: Heart consciousness sees everything as One.

'Vaccines' and the soul

The foundation of Wetiko/Archon control of humans is the separation of incarnate five-sense mind from the infinite 'I' and closing the heart chakra where the True 'I' lives during a human life. The goal has been to achieve complete separation in both cases. I was interested therefore to read an account by a French energetic healer of what she said she experienced with a patient who had been given the 'Covid' vaccine. Genuine energy healers can sense information and consciousness fields at different levels of being which are referred to as 'subtle bodies'. She described treating the patient who later returned after having, without the healer's knowledge, two doses of the 'Covid vaccine'. The healer said:

I noticed immediately the change, very heavy energy emanating from [the] subtle bodies. The scariest thing was when I was working on the heart chakra, I connected with her soul: it was detached from the physical body, it had no contact and it was, as if it was floating in a state of total confusion: a damage to the consciousness that loses contact with the physical body, i.e. with our biological machine, there is no longer any communication between them.

I continued the treatment by sending light to the heart chakra, the soul of the person, but it seemed that the soul could no longer receive any light, frequency or energy. It was a very powerful experience for me. Then I understood that this substance is indeed used to detach consciousness so that this consciousness can no longer interact through this body that it possesses in life, where there is no longer any contact, no frequency, no light, no more energetic balance or mind.

This would create a human that is rudderless and at the extreme almost zombie-like operating with a fractional state of consciousness at the mercy of Wetiko. I was especially intrigued by what the healer said in the light of the prediction by the highly-informed Rudolf Steiner more than a hundred years ago. He said:

In the future, we will eliminate the soul with medicine. Under the pretext of a 'healthy point of view', there will be a vaccine by which the human body will be treated as soon as possible directly at birth, so that the human being cannot develop the thought of the existence of soul and Spirit. To materialistic doctors will be entrusted the task of removing the soul of humanity.

As today, people are vaccinated against this disease or that disease, so in the future, children will be vaccinated with a substance that can be produced precisely in such a way that people, thanks to this vaccination, will be immune to being subjected to the 'madness' of spiritual life. He would be extremely smart, but he would not develop a conscience, and that is the true goal of some materialistic circles.

Steiner said the vaccine would detach the physical body from the etheric body (subtle bodies) and 'once the etheric body is detached the relationship between the universe and the etheric body would become extremely unstable, and man would become an automaton'. He said 'the physical body of man must be polished on this Earth by spiritual will – so the vaccine becomes a kind of arymanique (Wetiko) force' and 'man can no longer get rid of a given materialistic feeling'. Humans would then, he said, become 'materialistic of constitution and can no longer rise to the spiritual'. I have been writing for years about DNA being a receiver-transmitter of information that connects us to other levels of reality and these 'vaccines' changing DNA can be likened to changing an antenna and what it can transmit and receive. Such a disconnection would clearly lead to changes in personality and perception. Steiner further predicted the arrival of AI. Big Pharma 'Covid vaccine' makers, expressions of Wetiko, are testing their DNA-manipulating evil on children as I write with a view to giving the 'vaccine' to babies. If it's a soul-body disconnector – and I say that it is or can be – every child would be disconnected from 'soul' at birth and the 'vaccine' would create a closed system in which spiritual guidance from the greater self would play no part. This has been the ambition of Wetiko all

along. A Pentagon video from 2005 was leaked of a presentation explaining the development of vaccines to change behaviour by their effect on the brain. Those that believe this is not happening with the 'Covid' genetically-modifying procedure masquerading as a 'vaccine' should make an urgent appointment with Naivety Anonymous. Klaus Schwab wrote in 2018:

> Neurotechnologies enable us to better influence consciousness and thought and to understand many activities of the brain. They include decoding what we are thinking in fine levels of detail through new chemicals and interventions that can influence our brains to correct for errors or enhance functionality.

The plan is clear and only the heart can stop it. With every heart that opens, every mind that awakens, Wetiko is weakened. Heart and love are far more powerful than head and hate and so nothing like a majority is needed to turn this around.

Beyond the Phantom

Our heart is the prime target of Wetiko and so it must be the answer to Wetiko. We *are* our heart which is part of one heart, the infinite heart. Our heart is where the true self lives in a human life behind firewalls of five-sense illusion when an imposter takes its place – *Phantom Self*; but our heart waits patiently to be set free any time we choose to see beyond the Phantom, beyond Wetiko. A Wetikoed Phantom Self can wreak mass death and destruction while the love of forever is locked away in its heart. The time is here to unleash its power and let it sweep away the fear and despair that is Wetiko. Heart consciousness does not seek manipulated, censored, advantage for its belief or religion, its activism and desires. As an expression of the One it treats all as One with the same rights to freedom and opinion. Our heart demands fairness for itself no more than for others. From this unity of heart we can come together in mutual support and transform this Wetikoed world into what reality is meant to be – a place of love, joy, happiness, fairness, justice and freedom. Wetiko has another agenda and that's why the world is as

it is, but enough of this nonsense. Wetiko can't stay where hearts are open and it works so hard to keep them closed. Fear is its currency and its food source and love in its true sense has no fear. Why would love have fear when it knows it is *All That Is, Has Been, And Ever Can Be* on an eternal exploration of all possibility? Love in this true sense is not the physical attraction that passes for love. This can be an expression of it, yes, but Infinite Love, a love without condition, goes far deeper to the core of all being. It *is* the core of all being. Infinite realty was born from love beyond the illusions of the simulation. Love infinitely expressed is the knowing that all is One and the swiftly-passing experience of separation is a temporary hallucination. You cannot disconnect from Oneness; you can only *perceive* that you have and withdraw from its influence. This is the most important of all perception trickery by the mind parasite that is Wetiko and the foundation of all its potential for manipulation.

If we open our hearts, open the sluice gates of the mind, and redefine self-identity amazing things start to happen. Consciousness expands or contracts in accordance with self-identity. When true self is recognised as infinite awareness and label self – Phantom Self – is seen as only a series of brief experiences life is transformed. Consciousness expands to the extent that self-identity expands and everything changes. You see unity, not division, the picture, not the pixels. From this we can play the long game. No more is an experience something in and of itself, but a fleeting moment in the eternity of forever. Suddenly people in uniform and dark suits are no longer intimidating. Doing what your heart knows to be right is no longer intimidating and consequences for those actions take on the same nature of a brief experience that passes in the blink of an infinite eye. Intimidation is all in the mind. Beyond the mind there is no intimidation.

An open heart does not consider consequences for what it knows to be right. To do so would be to consider not doing what it knows to be right and for a heart in its power that is never an option. The Renegade Mind is really the Renegade Heart. Consideration of consequences will always provide a getaway car for the mind and

the heart doesn't want one. What is right in the light of what we face today is to stop cooperating with Wetiko in all its forms and to do it without fear or compromise. You cannot compromise with tyranny when tyranny always demands more until it has everything. Life is your perception and you are your destiny. Change your perception and you change your life. Change collective perception and we change the world.

Come on people … One human family, One heart, One goal … *FREEEEEEDOM*!

We must settle for nothing less.

Postscript

The big scare story as the book goes to press is the 'Indian' variant and the world is being deluged with propaganda about the 'Covid catastrophe' in India which mirrors in its lies and misrepresentations what happened in Italy before the first lockdown in 2020.

The *New York Post* published a picture of someone who had 'collapsed in the street from Covid' in India in April, 2021, which was actually taken during a gas leak in May, 2020. Same old, same old. Media articles in mid-February were asking why India had been so untouched by 'Covid' and then as their vaccine rollout gathered pace the alleged 'cases' began to rapidly increase. Indian 'Covid vaccine' maker Bharat Biotech was funded into existence by the Bill and Melinda Gates Foundation (the pair announced their divorce in May, 2021, which is a pity because they so deserve each other). The Indian 'Covid crisis' was ramped up by the media to terrify the world and prepare people for submission to still more restrictions. The scam that worked the first time was being repeated only with far more people seeing through the deceit. Davidicke.com and Ickonic.com have sought to tell the true story of what is happening by talking to people living through the Indian nightmare which has nothing to do with 'Covid'. We posted a letter from 'Alisha' in Pune who told a very different story to government and media mendacity. She said scenes of dying people and overwhelmed hospitals were designed to hide what was really happening – genocide and starvation. Alisha said that millions had already died of starvation during the ongoing lockdowns while government and media were lying and making it look like the 'virus':

Restaurants, shops, gyms, theatres, basically everything is shut. The cities are ghost towns. Even so-called 'essential' businesses are only open till 11am in the morning. You basically have just an hour to buy food and then your time is up.

Inter-state travel and even inter-district travel is banned. The cops wait at all major crossroads to question why you are traveling outdoors or to fine you if you are not wearing a mask.

The medical community here is also complicit in genocide, lying about hospitals being full and turning away people with genuine illnesses, who need immediate care. They have even created a shortage of oxygen cylinders.

This is the classic Cult modus operandi played out in every country. Alisha said that people who would not have a PCR test not testing for the 'virus' were being denied hospital treatment. She said the people hit hardest were migrant workers and those in rural areas. Most businesses employed migrant workers and with everything closed there were no jobs, no income and no food. As a result millions were dying of starvation or malnutrition. All this was happening under Prime Minister Narendra Modi, a 100-percent asset of the Cult, and it emphasises yet again the scale of pure anti-human evil we are dealing with. Australia banned its people from returning home from India with penalties for trying to do so of up to five years in jail and a fine of £37,000. The manufactured 'Covid' crisis in India was being prepared to justify further fascism in the West. Obvious connections could be seen between the Indian 'vaccine' programme and increased 'cases' and this became a common theme. The Seychelles, the most per capita 'Covid vaccinated' population in the world, went back into lockdown after a 'surge of cases'.

Long ago the truly evil Monsanto agricultural biotechnology corporation with its big connections to Bill Gates devastated Indian farming with genetically-modified crops. Human rights activist Gurcharan Singh highlighted the efforts by the Indian government to complete the job by destroying the food supply to hundreds of millions with 'Covid' lockdowns. He said that 415 million people at the bottom of the disgusting caste system (still going whatever they say) were below the poverty line and struggled to feed themselves every year. Now the government was imposing lockdown at just the

time to destroy the harvest. This deliberate policy was leading to mass starvation. People may reel back at the suggestion that a government would do that, but Wetiko-controlled 'leaders' are capable of any level of evil. In fact what is described in India is in the process of being instigated worldwide. The food chain and food supply are being targeted at every level to cause world hunger and thus control. Bill Gates is not the biggest owner of farmland in America for no reason and destroying access to food aids both the depopulation agenda and the plan for synthetic 'food' already being funded into existence by Gates. Add to this the coming hyper-inflation from the suicidal creation of fake 'money' in response to 'Covid' and the breakdown of container shipping systems and you have a cocktail that can only lead one way and is meant to. The Cult plan is to crash the entire system to 'build back better' with the Great Reset.

'Vaccine' transmission

Reports from all over the world continue to emerge of women suffering menstrual and fertility problems after having the fake 'vaccine' and of the non-'vaccinated' having similar problems when interacting with the 'vaccinated'. There are far too many for 'coincidence' to be credible. We've had menopausal women getting periods, others having periods stop or not stopping for weeks, passing clots, sometimes the lining of the uterus, breast irregularities, and miscarriages (which increased by 400 percent in parts of the United States). Non-'vaccinated' men and children have suffered blood clots and nose bleeding after interaction with the 'vaccinated'. Babies have died from the effects of breast milk from a 'vaccinated' mother. Awake doctors – the small minority – speculated on the cause of non-'vaccinated' suffering the same effects as the 'vaccinated'. Was it nanotechnology in the synthetic substance transmitting frequencies or was it a straight chemical bioweapon that was being transmitted between people? I am not saying that some kind of chemical transmission is not one possible answer, but the foundation of all that the Cult does is frequency and

this is fertile ground for understanding how transmission can happen. American doctor Carrie Madej, an internal medicine physician and osteopath, has been practicing for the last 20 years, teaching medical students, and she says attending different meetings where the agenda for humanity was discussed. Madej, who operates out of Georgia, did not dismiss other possible forms of transmission, but she focused on frequency in search of an explanation for transmission. She said the Moderna and Pfizer 'vaccines' contained nano-lipid particles as a key component. This was a brand new technology never before used on humanity. 'They're using a nanotechnology which is pretty much little tiny computer bits … nanobots or hydrogel.' Inside the 'vaccines' was 'this sci-fi kind of substance' which suppressed immune checkpoints to get into the cell. I referred to this earlier as the 'Trojan horse' technique that tricks the cell into opening a gateway for the self-replicating synthetic material and while the immune system is artificially suppressed the body has no defences. Madej said the substance served many purposes including an on-demand ability to 'deliver the payload' and using the nano 'computer bits' as biosensors in the body. 'It actually has the ability to accumulate data from your body, like your breathing, your respiration, thoughts, emotions, all kinds of things.'

She said the technology obviously has the ability to operate through Wi-Fi and transmit and receive energy, messages, frequencies or impulses. 'Just imagine you're getting this new substance in you and it can react to things all around you, the 5G, your smart device, your phones.' We had something completely foreign in the human body that had never been launched large scale at a time when we were seeing 5G going into schools and hospitals (plus the Musk satellites) and she believed the 'vaccine' transmission had something to do with this: '… if these people have this inside of them … it can act like an antenna and actually transmit it outwardly as well.' The synthetic substance produced its own voltage and so it could have that kind of effect. This fits with my own contention that the nano receiver-transmitters are designed to connect people to the

Smart Grid and break the receiver-transmitter connection to expanded consciousness. That would explain the French energy healer's experience of the disconnection of body from 'soul' with those who have had the 'vaccine'. The nanobots, self-replicating inside the body, would also transmit the synthetic frequency which could be picked up through close interaction by those who have not been 'vaccinated'. Madej speculated that perhaps it was 5G and increased levels of other radiation that was causing the symptoms directly although interestingly she said that non-'vaccinated' patients had shown improvement when they were away from the 'vaccinated' person they had interacted with. It must be remembered that you can control frequency and energy with your mind and you can consciously create energetic barriers or bubbles with the mind to stop damaging frequencies from penetrating your field. American paediatrician Dr Larry Palevsky said the 'vaccine' was not a 'vaccine' and was never designed to protect from a 'viral' infection. He called it 'a massive, brilliant propaganda of genocide' because they didn't have to inject everyone to get the result they wanted. He said the content of the jabs was able to infuse any material into the brain, heart, lungs, kidneys, liver, sperm and female productive system. 'This is genocide; this is a weapon of mass destruction.' At the same time American colleges were banning students from attending if they didn't have this life-changing and potentially life-ending 'vaccine'. Class action lawsuits must follow when the consequences of this college fascism come to light. As the book was going to press came reports about fertility effects on sperm in 'vaccinated' men which would absolutely fit with what I have been saying and hospitals continued to fill with 'vaccine' reactions. Another question is what about transmission via blood transfusions? The NHS has extended blood donation restrictions from seven days after a 'Covid vaccination' to 28 days after even a sore arm reaction.

I said in the spring of 2020 that the then touted 'Covid vaccine' would be ongoing each year like the flu jab. A year later Pfizer CEO, the appalling Albert Bourla, said people would 'likely' need a 'booster dose' of the 'vaccine' within 12 months of getting 'fully

vaccinated' and then a yearly shot. 'Variants will play a key role', he said confirming the point. Johnson & Johnson CEO Alex Gorsky also took time out from his 'vaccine' disaster to say that people may need to be vaccinated against 'Covid-19' each year. UK Health Secretary, the psychopath Matt Hancock, said additional 'boosters' would be available in the autumn of 2021. This is the trap of the 'vaccine passport'. The public will have to accept every last 'vaccine' they introduce, including for the fake 'variants', or it would cease to be valid. The only other way in some cases would be continuous testing with a test not testing for the 'virus' and what is on the swabs constantly pushed up your noise towards the brain every time?

'Vaccines' changing behaviour

I mentioned in the body of the book how I believed we would see gathering behaviour changes in the 'vaccinated' and I am already hearing such comments from the non-'vaccinated' describing behaviour changes in friends, loved ones and work colleagues. This will only increase as the self-replicating synthetic material and nanoparticles expand in body and brain. An article in the *Guardian* in 2016 detailed research at the University of Virginia in Charlottesville which developed a new method for controlling brain circuits associated with complex animal behaviour. The method, dubbed 'magnetogenetics', involves genetically-engineering a protein called ferritin, which stores and releases iron, to create a magnetised substance – 'Magneto' – that can activate specific groups of nerve cells from a distance. This is claimed to be an advance on other methods of brain activity manipulation known as optogenetics and chemogenetics (the Cult has been developing methods of brain control for a long time). The ferritin technique is said to be non-invasive and able to activate neurons 'rapidly and reversibly'. In other words, human thought and perception. The article said that earlier studies revealed how nerve cell proteins 'activated by heat and mechanical pressure can be genetically engineered so that they become sensitive to radio waves and magnetic fields, by attaching them to an iron-storing protein called ferritin, or to inorganic

paramagnetic particles'. Sensitive to radio waves and magnetic fields? You mean like 5G, 6G and 7G? This is the human-AI Smart Grid hive mind we are talking about. The *Guardian* article said:

> … the researchers injected Magneto into the striatum of freely behaving mice, a deep brain structure containing dopamine-producing neurons that are involved in reward and motivation, and then placed the animals into an apparatus split into magnetised and non-magnetised sections.
>
> Mice expressing Magneto spent far more time in the magnetised areas than mice that did not, because activation of the protein caused the striatal neurons expressing it to release dopamine, so that the mice found being in those areas rewarding. This shows that Magneto can remotely control the firing of neurons deep within the brain, and also control complex behaviours.

Make no mistake this basic methodology will be part of the 'Covid vaccine' cocktail and using magnetics to change brain function through electromagnetic field frequency activation. The Pentagon is developing a 'Covid vaccine' using ferritin. Magnetics would explain changes in behaviour and why videos are appearing across the Internet as I write showing how magnets stick to the skin at the point of the 'vaccine' shot. Once people take these 'vaccines' anything becomes possible in terms of brain function and illness which will be blamed on 'Covid-19' and 'variants'. Magnetic field manipulation would further explain why the non-'vaccinated' are reporting the same symptoms as the 'vaccinated' they interact with and why those symptoms are reported to decrease when not in their company. Interestingly 'Magneto', a 'mutant', is a character in the Marvel Comic *X-Men* stories with the ability to manipulate magnetic fields and he believes that mutants should fight back against their human oppressors by any means necessary. The character was born Erik Lehnsherr to a Jewish family in Germany.

Cult-controlled courts

The European Court of Human Rights opened the door for mandatory 'Covid-19 vaccines' across the continent when it ruled in a Czech Republic dispute over childhood immunisation that legally

enforced vaccination could be 'necessary in a democratic society'. The 17 judges decided that compulsory vaccinations did not breach human rights law. On the face of it the judgement was so inverted you gasp for air. If not having a vaccine infused into your body is not a human right then what is? Ah, but they said human rights law which has been specifically written to delete all human rights at the behest of the state (the Cult). Article 8 of the European Convention on Human Rights relates to the right to a private life. The crucial word here is *'except'*:

> There shall be no interference by a public authority with the exercise of this right EXCEPT such as is in accordance with the law and is necessary in a democratic society in the interests of national security, public safety or the economic wellbeing of the country, for the prevention of disorder or crime, for the protection of health or morals, or for the protection of the rights and freedoms of others [My emphasis].

No interference *except* in accordance with the law means there *are* no 'human rights' *except* what EU governments decide you can have at their behest. 'As is necessary in a democratic society' explains that reference in the judgement and 'in the interests of national security, public safety or the economic well-being of the country, for the prevention of disorder or crime, for the protection of health or morals, or for the protection of the rights and freedoms of others' gives the EU a coach and horses to ride through 'human rights' and scatter them in all directions. The judiciary is not a check and balance on government extremism; it is a vehicle to enforce it. This judgement was almost laughably predictable when the last thing the Cult wanted was a decision that went against mandatory vaccination. Judges rule over and over again to benefit the system of which they are a part. Vaccination disputes that come before them are invariably delivered in favour of doctors and authorities representing the view of the state which owns the judiciary. Oh, yes, and we have even had calls to stop putting 'Covid-19' on death certificates within 28 days of a 'positive test' because it is claimed the practice makes the 'vaccine' appear not to work. They are laughing at you.

The scale of madness, inhumanity and things to come was highlighted when those not 'vaccinated' for 'Covid' were refused evacuation from the Caribbean island of St Vincent during massive volcanic eruptions. Cruise ships taking residents to the safety of another island allowed only the 'vaccinated' to board and the rest were left to their fate. Even in life and death situations like this we see 'Covid' stripping people of their most basic human instincts and the insanity is even more extreme when you think that fake 'vaccine'-makers are not even claiming their body-manipulating concoctions stop 'infection' and 'transmission' of a 'virus' that doesn't exist. St Vincent Prime Minister Ralph Gonsalves said: 'The chief medical officer will be identifying the persons already vaccinated so that we can get them on the ship.' Note again the power of the chief medical officer who, like Whitty in the UK, will be answering to the World Health Organization. This is the Cult network structure that has overridden politicians who 'follow the science' which means doing what WHO-controlled 'medical officers' and 'science advisers' tell them. Gonsalves even said that residents who were 'vaccinated' after the order so they could board the ships would still be refused entry due to possible side effects such as 'wooziness in the head'. The good news is that if they were woozy enough in the head they could qualify to be prime minister of St Vincent.

Microchipping freedom

The European judgement will be used at some point to justify moves to enforce the 'Covid' DNA-manipulating procedure. Sandra Ro, CEO of the Global Blockchain Business Council, told a World Economic Forum event that she hoped 'vaccine passports' would help to 'drive forced consent and standardisation' of global digital identity schemes: 'I'm hoping with the desire and global demand for some sort of vaccine passport – so that people can get travelling and working again – [it] will drive forced consent, standardisation, and frankly, cooperation across the world.' The lady is either not very bright, or thoroughly mendacious, to use the term 'forced consent'.

You do not 'consent' if you are forced – you *submit*. She was describing what the plan has been all along and that's to enforce a digital identity on every human without which they could not function. 'Vaccine passports' are opening the door and are far from the end goal. A digital identity would allow you to be tracked in everything you do in cyberspace and this is the same technique used by Cult-owned China to enforce its social credit system of total control. The ultimate 'passport' is planned to be a microchip as my books have warned for nearly 30 years. Those nice people at the Pentagon working for the Cult-controlled Defense Advanced Research Projects Agency (DARPA) claimed in April, 2021, they have developed a microchip inserted under the skin to detect 'asymptomatic Covid-19 infection' before it becomes an outbreak and a 'revolutionary filter' that can remove the 'virus' from the blood when attached to a dialysis machine. The only problems with this are that the 'virus' does not exist and people transmitting the 'virus' with no symptoms is brain-numbing bullshit. This is, of course, not a ruse to get people to be microchipped for very different reasons. DARPA also said it was producing a one-stop 'vaccine' for the 'virus' and all 'variants'. One of the most sinister organisations on Planet Earth is doing this? Better have it then. These people are insane because Wetiko that possesses them is insane.

Researchers from the Salk Institute in California announced they have created an embryo that is part human and part monkey. My books going back to the 1990s have exposed experiments in top secret underground facilities in the United States where humans are being crossed with animal and non-human 'extraterrestrial' species. They are now easing that long-developed capability into the public arena and there is much more to come given we are dealing with psychiatric basket cases. Talking of which – Elon Musk's scientists at Neuralink trained a monkey to play Pong and other puzzles on a computer screen using a joystick and when the monkey made the correct move a metal tube squirted banana smoothie into his mouth which is the basic technique for training humans into unquestioning compliance. Two Neuralink chips were in the monkey's skull and

more than 2,000 wires 'fanned out' into its brain. Eventually the monkey played a video game purely with its brain waves. Psychopathic narcissist Musk said the 'breakthrough' was a step towards putting Neuralink chips into human skulls and merging minds with artificial intelligence. *Exactly*. This man is so dark and Cult to his DNA.

World Economic Fascism (WEF)

The World Economic Forum is telling you the plan by the statements made at its many and various events. Cult-owned fascist YouTube CEO Susan Wojcicki spoke at the 2021 WEF Global Technology Governance Summit (see the name) in which 40 governments and 150 companies met to ensure 'the responsible design and deployment of emerging technologies'. Orwellian translation: 'Ensuring the design and deployment of long-planned technologies will advance the Cult agenda for control and censorship.' Freedom-destroyer and Nuremberg-bound Wojcicki expressed support for tech platforms like hers to censor content that is 'technically legal but could be harmful'. Who decides what is 'harmful'? She does and they do. 'Harmful' will be whatever the Cult doesn't want people to see and we have legislation proposed by the UK government that would censor content on the basis of 'harm' no matter if the information is fair, legal and provably true. Make that *especially* if it is fair, legal and provably true. Wojcicki called for a global coalition to be formed to enforce content moderation standards through automated censorship. This is a woman and mega-censor so self-deluded that she shamelessly accepted a 'free expression' award – *Wojcicki* – in an event sponsored by her own *YouTube*. They have no shame and no self-awareness.

You know that 'Covid' is a scam and Wojcicki a Cult operative when YouTube is censoring medical and scientific opinion purely on the grounds of whether it supports or opposes the Cult 'Covid' narrative. Florida governor Ron DeSantis compiled an expert panel with four professors of medicine from Harvard, Oxford, and Stanford Universities who spoke against forcing children and

vaccinated people to wear masks. They also said there was no proof that lockdowns reduced spread or death rates of 'Covid-19'. Cult-gofer Wojcicki and her YouTube deleted the panel video 'because it included content that contradicts the consensus of local and global health authorities regarding the efficacy of masks to prevent the spread of Covid-19'. This 'consensus' refers to what the Cult tells the World Health Organization to say and the WHO tells 'local health authorities' to do. Wojcicki knows this, of course. The panellists pointed out that censorship of scientific debate was responsible for deaths from many causes, but Wojcicki couldn't care less. She would not dare go against what she is told and as a disgrace to humanity she wouldn't want to anyway. The UK government is seeking to pass a fascist 'Online Safety Bill' to specifically target with massive fines and other means non-censored video and social media platforms to make them censor 'lawful but harmful' content like the Cult-owned Facebook, Twitter, Google and YouTube. What is 'lawful but harmful' would be decided by the fascist Blair-created Ofcom.

Another WEF obsession is a cyber-attack on the financial system and this is clearly what the Cult has planned to take down the bank accounts of everyone – except theirs. Those that think they have enough money for the Cult agenda not to matter to them have got a big lesson coming if they continue to ignore what is staring them in the face. The World Economic Forum, funded by Gates and fronted by Klaus Schwab, announced it would be running a 'simulation' with the Russian government and global banks of just such an attack called Cyber Polygon 2021. What they simulate – as with the 'Covid' Event 201 – they plan to instigate. The WEF is involved in a project with the Cult-owned Carnegie Endowment for International Peace called the WEF-Carnegie Cyber Policy Initiative which seeks to merge Wall Street banks, 'regulators' (I love it) and intelligence agencies to 'prevent' (arrange and allow) a cyber-attack that would bring down the global financial system as long planned by those that control the WEF and the Carnegie operation. The Carnegie Endowment for International Peace sent an instruction to First World

War US President Woodrow Wilson not to let the war end before society had been irreversibly transformed.

The Wuhan lab diversion

As I close, the Cult-controlled authorities and lapdog media are systematically pushing 'the virus was released from the Wuhan lab' narrative. There are two versions – it happened by accident and it happened on purpose. Both are nonsense. The perceived existence of the never-shown-to-exist 'virus' is vital to sell the impression that there is actually an infective agent to deal with and to allow the endless potential for terrifying the population with 'variants' of a 'virus' that does not exist. The authorities at the time of writing are going with the 'by accident' while the alternative media is promoting the 'on purpose'. Cable news host Tucker Carlson who has questioned aspects of lockdown and 'vaccine' compulsion has bought the Wuhan lab story. 'Everyone now agrees' he said. Well, I don't and many others don't and the question is *why* does the system and its media suddenly 'agree'? When the media moves as one unit with a narrative it is always a lie – witness the hour by hour mendacity of the 'Covid' era. Why would this Cult-owned combination which has unleashed lies like machine gun fire suddenly 'agree' to tell the truth??

Much of the alternative media is buying the lie because it fits the conspiracy narrative, but it's the *wrong* conspiracy. The real conspiracy is that *there is no virus* and that is what the Cult is desperate to hide. The idea that the 'virus' was released by accident is ludicrous when the whole 'Covid' hoax was clearly long-planned and waiting to be played out as it was so fast in accordance with the Rockefeller document and Event 201. So they prepared everything in detail over decades and then sat around strumming their fingers waiting for an 'accidental' release from a bio-lab? *What??* It's crazy. Then there's the 'on purpose' claim. You want to circulate a 'deadly virus' and hide the fact that you've done so and you release it down the street from the highest-level bio-lab in China? I repeat – *What??*

You would release it far from that lab to stop any association being made. But, no, we'll do it in a place where the connection was certain to be made. Why would you need to scam 'cases' and 'deaths' and pay hospitals to diagnose 'Covid-19' if you had a real 'virus'? What are sections of the alternative media doing believing this crap? Where were all the mass deaths in Wuhan from a 'deadly pathogen' when the recovery to normal life after the initial propaganda was dramatic in speed? Why isn't the 'deadly pathogen' now circulating all over China with bodies in the street? Once again we have the technique of tell them what they want to hear and they will likely believe it. The alternative media has its 'conspiracy' and with Carlson it fits with his 'China is the danger' narrative over years. China *is* a danger as a global Cult operations centre, but not for this reason. The Wuhan lab story also has the potential to instigate conflict with China when at some stage the plan is to trigger a Problem-Reaction-Solution confrontation with the West. Question everything – *everything* – and especially when the media agrees on a common party line.

Third wave ... fourth wave ... fifth wave ...

As the book went into production the world was being set up for more lockdowns and a 'third wave' supported by invented 'variants' that were increasing all the time and will continue to do so in public statements and computer programs, but not in reality. India became the new Italy in the 'Covid' propaganda campaign and we were told to be frightened of the new 'Indian strain'. Somehow I couldn't find it within myself to do so. A document produced for the UK government entitled 'Summary of further modelling of easing of restrictions – Roadmap Step 2' declared that a third wave was inevitable (of course when it's in the script) and it would be the fault of children and those who refuse the health-destroying fake 'Covid vaccine'. One of the computer models involved came from the Cult-owned *Imperial College* and the other from Warwick University which I wouldn't trust to tell me the date in a calendar factory. The document states that both models presumed extremely high uptake

of the 'Covid vaccines' and didn't allow for 'variants'. The document states: 'The resurgence is a result of some people (mostly children) being ineligible for vaccination; others choosing not to receive the vaccine; and others being vaccinated but not perfectly protected.' The mendacity takes the breath away. Okay, blame those with a brain who won't take the DNA-modifying shots and put more pressure on children to have it as 'trials' were underway involving children as young as six months with parents who give insanity a bad name. Massive pressure is being put on the young to have the fake 'vaccine' and child age consent limits have been systematically lowered around the world to stop parents intervening. Most extraordinary about the document was its claim that the 'third wave' would be driven by 'the resurgence in both hospitalisations and deaths … dominated by *those that have received two doses of the vaccine*, comprising around 60-70% of the wave respectively'. The predicted peak of the 'third wave' suggested 300 deaths per day with 250 of them *fully 'vaccinated' people*. How many more lies do acquiescers need to be told before they see the obvious? Those who took the jab to 'protect themselves' are projected to be those who mostly get sick and die? So what's in the 'vaccine'? The document went on:

> It is possible that a summer of low prevalence could be followed by substantial increases in incidence over the following autumn and winter. Low prevalence in late summer should not be taken as an indication that SARS-CoV-2 has retreated or that the population has high enough levels of immunity to prevent another wave.

They are telling you the script and while many British people believed 'Covid' restrictions would end in the summer of 2021 the government was preparing for them to be ongoing. Authorities were awarding contracts for 'Covid marshals' to police the restrictions with contracts starting in July, 2021, and going through to January 31st, 2022, and the government was advertising for 'Media Buying Services' to secure media propaganda slots worth a potential £320 million for 'Covid-19 campaigns' with a contract not ending until March, 2022. The recipient – via a list of other front companies – was reported to be American media marketing giant Omnicom Group

Inc. While money is no object for 'Covid' the UK waiting list for all other treatment – including life-threatening conditions – passed 4.5 million. Meantime the Cult is seeking to control all official 'inquiries' to block revelations about what has really been happening and why. It must not be allowed to – we need Nuremberg jury trials in every country. The cover-up doesn't get more obvious than appointing ultra-Zionist professor Philip Zelikow to oversee two dozen US virologists, public health officials, clinicians, former government officials and four American 'charitable foundations' to 'learn the lessons' of the 'Covid' debacle. The personnel will be those that created and perpetuated the 'Covid' lies while Zelikow is the former executive director of the 9/11 Commission who ensured that the truth about those attacks never came out and produced a report that must be among the most mendacious and manipulative documents ever written – see *The Trigger* for the detailed exposure of the almost unimaginable 9/11 story in which Sabbatians can be found at every level.

Passive no more

People are increasingly challenging the authorities with amazing numbers of people taking to the streets in London well beyond the ability of the Face-Nappies to stop them. Instead the Nappies choose situations away from the mass crowds to target, intimidate, and seek to promote the impression of 'violent protestors'. One such incident happened in London's Hyde Park. Hundreds of thousands walking through the streets in protest against 'Covid' fascism were ignored by the Cult-owned BBC and most of the rest of the mainstream media, but they delighted in reporting how police were injured in 'clashes with protestors'. The truth was that a group of people gathered in Hyde Park at the end of one march when most had gone home and they were peacefully having a good time with music and chat. Face-Nappies who couldn't deal with the full-march crowd then waded in with their batons and got more than they bargained for. Instead of just standing for this criminal brutality the crowd used their numerical superiority to push the Face-Nappies out of the

park. Eventually the Nappies turned and ran. Unfortunately two or three idiots in the crowd threw drink cans striking two officers which gave the media and the government the image they wanted to discredit the 99.9999 percent who were peaceful. The idiots walked straight into the trap and we must always be aware of potential agent provocateurs used by the authorities to discredit their targets.

This response from the crowd – the can people apart – must be a turning point when the public no longer stand by while the innocent are arrested and brutally attacked by the Face-Nappies. That doesn't mean to be violent, that's the last thing we need. We'll leave the violence to the Face-Nappies and government. But it does mean that when the Face-Nappies use violence against peaceful people the numerical superiority is employed to stop them and make citizen's arrests or Common Law arrests for a breach of the peace. The time for being passive in the face of fascism is over.

We are the many, they are the few, and we need to make that count before there is no freedom left and our children and grandchildren face an ongoing fascist nightmare.

COME ON PEOPLE – IT'S TIME.

One final thought …

The power of love
A force from above
Cleaning my soul
Flame on burn desire
Love with tongues of fire
Purge the soul
Make love your goal

I'll protect you from the hooded claw
Keep the vampires from your door
When the chips are down I'll be around
With my undying, death-defying
Love for you

Envy will hurt itself
Let yourself be beautiful
Sparkling love, flowers
And pearls and pretty girls
Love is like an energy
Rushin' rushin' inside of me

This time we go sublime
Lovers entwine, divine, divine,
Love is danger, love is pleasure
Love is pure – the only treasure

I'm so in love with you
Purge the soul
Make love your goal

The power of love
A force from above
Cleaning my soul
The power of love
A force from above
A sky-scraping dove

Flame on burn desire
Love with tongues of fire
Purge the soul
Make love your goal

Frankie Goes To Hollywood

APPENDIX

Cowan-Kaufman-Morell Statement on Virus Isolation (SOVI)

Isolation: The action of isolating; the fact or condition of being isolated or standing alone; separation from other things or persons; solitariness
Oxford English Dictionary

The controversy over whether the SARS-CoV-2 virus has ever been isolated or purified continues. However, using the above definition, common sense, the laws of logic and the dictates of science, any unbiased person must come to the conclusion that the SARS-CoV-2 virus has never been isolated or purified. As a result, no confirmation of the virus' existence can be found. The logical, common sense, and scientific consequences of this fact are:

- the structure and composition of something not shown to exist can't be known, including the presence, structure, and function of any hypothetical spike or other proteins;
- the genetic sequence of something that has never been found can't be known;
- "variants" of something that hasn't been shown to exist can't be known;
- it's impossible to demonstrate that SARS-CoV-2 causes a disease called Covid-19.

In as concise terms as possible, here's the proper way to isolate, characterize and demonstrate a new virus. First, one takes samples (blood, sputum, secretions) from many people (e.g. 500) with symptoms which are unique and specific enough to characterize an illness. Without mixing these samples with ANY tissue or products that also contain genetic material, the virologist macerates, filters and ultracentrifuges i.e. *purifies* the specimen. This common virology technique, done for decades to isolate bacteriophages[1] and so-called giant viruses in every virology lab, then allows the virologist to demonstrate with electron microscopy thousands of identically sized and shaped particles. These particles are the isolated and purified virus.

These identical particles are then checked for uniformity by physical and/or microscopic techniques. Once the purity is determined, the particles may be further characterized. This would include examining the structure, morphology, and chemical composition of the particles. Next, their genetic makeup is characterized by extracting the genetic material directly from the purified particles and using genetic-sequencing techniques, such as Sanger sequencing, that have also been around for decades. Then one does an analysis to confirm that these uniform particles are exogenous (outside) in origin as a virus is conceptualized to be, and not the normal breakdown products of dead and dying tissues.[2] (As of May 2020, we know that virologists have no way to determine whether the particles they're seeing are viruses or just normal breakdown products of dead and dying tissues.)[3]

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1 Isolation, characterization and analysis of bacteriophages from the haloalkaline lake Elmenteita, KenyaJuliah Khayeli Akhwale et al, PLOS One, Published: April 25, 2019. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0215734 – accessed 2/15/21

2 "Extracellular Vesicles Derived From Apoptotic Cells: An Essential Link Between Death and Regeneration," Maojiao Li1 et al, Frontiers in Cell and Developmental Biology, 2020 October 2. https://www.frontiersin.org/articles/10.3389/fcell.2020.573511/full – accessed 2/15/21

3 "The Role of Extraellular Vesicles as Allies of HIV, HCV and SARS Viruses," Flavia Giannessi, et al, Viruses, 2020 May

If we have come this far then we have fully isolated, characterized, and genetically sequenced an exogenous virus particle. However, we still have to show it is causally related to a disease. This is carried out by exposing a group of healthy subjects (animals are usually used) to this isolated, purified virus in the manner in which the disease is thought to be transmitted. If the animals get sick with the same disease, as confirmed by clinical and autopsy findings, one has now shown that the virus actually causes a disease. This demonstrates infectivity and transmission of an infectious agent.

None of these steps has even been attempted with the SARS-CoV-2 virus, nor have all these steps been successfully performed for any so-called pathogenic virus. Our research indicates that a single study showing these steps does not exist in the medical literature.

Instead, since 1954, virologists have taken unpurified samples from a relatively few people, often less than ten, with a similar disease. They then minimally process this sample and inoculate this unpurified sample onto tissue culture containing usually four to six other types of material – all of which contain identical genetic material as to what is called a "virus." The tissue culture is starved and poisoned and naturally disintegrates into many types of particles, some of which contain genetic material. Against all common sense, logic, use of the English language and scientific integrity, this process is called "virus isolation." This brew containing fragments of genetic material from many sources is then subjected to genetic analysis, which then creates in a computer-simulation process the alleged sequence of the alleged virus, a so called in silico genome. At no time is an actual virus confirmed by electron microscopy. At no time is a genome extracted and sequenced from an actual virus. This is scientific fraud.

The observation that the unpurified specimen — inoculated onto tissue culture along with toxic antibiotics, bovine fetal tissue, amniotic fluid and other tissues — destroys the kidney tissue onto which it is inoculated is given as evidence of the virus' existence and pathogenicity. This is scientific fraud.

From now on, when anyone gives you a paper that suggests the SARS-CoV-2 virus has been isolated, please check the methods sections. If the researchers used Vero cells or any other culture method, you know that their process was not isolation. You will hear the following excuses for why actual isolation isn't done:

1. There were not enough virus particles found in samples from patients to analyze.

2. Viruses are intracellular parasites; they can't be found outside the cell in this manner.

If No. 1 is correct, and we can't find the virus in the sputum of sick people, then on what evidence do we think the virus is dangerous or even lethal? If No. 2 is correct, then how is the virus spread from person to person? We are told it emerges from the cell to infect others. Then why isn't it possible to find it?

Finally, questioning these virology techniques and conclusions is not some distraction or divisive issue. Shining the light on this truth is essential to stop this terrible fraud that humanity is confronting. For, as we now know, if the virus has never been isolated, sequenced or shown to cause illness, if the virus is imaginary, then why are we wearing masks, social distancing and putting the whole world into prison?

Finally, if pathogenic viruses don't exist, then what is going into those injectable devices erroneously called "vaccines," and what is their purpose? This scientific question is the most urgent and relevant one of our time.

We are correct. The SARS-CoV2 virus does not exist.

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Bibliography

Alinsky, Saul: *Rules for Radicals* (Vintage, 1989)

Antelman, Rabbi Marvin: *To Eliminate the Opiate* (Zahavia, 1974)

Bastardi, Joe: *The Climate Chronicles* (Relentless Thunder Press, 2018)

Cowan, Tom: *Human Heart, Cosmic Heart* (Chelsea Green Publishing, 2016)

Cowan, Tom, and Fallon Morell, Sally: *The Contagion Myth* (Skyhorse Publishing, 2020)

Forbes, Jack D: *Columbus And Other Cannibals – The Wetiko Disease of Exploitation, Imperialism, and Terrorism* (Seven Stories Press, 2008 – originally published in 1979)

Gates, Bill: *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need* (Allen Lane, 2021)

Huxley, Aldous: *Brave New World* (Chatto & Windus, 1932)

Köhnlein, Dr Claus, and Engelbrecht, Torsten: *Virus Mania* (emu-Vertag, Lahnstein, 2020)

Lanza, Robert, and Berman, Bob: *Biocentrism* (BenBella Books, 2010)

Lash, John Lamb: *Not In His Image* (Chelsea Green Publishing, 2006)

Lester, Dawn, and Parker, David: *What Really Makes You Ill – Why everything you thought you knew about disease is wrong* (Independently Published, 2019)

Levy, Paul: *Dispelling Wetiko, Breaking the Spell of Evil* (North Atlantic Books, 2013)

Marx, Karl: *A World Without Jews* (Philosophical Library, first edition, 1959)

Mullis, Kary: *Dancing Naked in the Mine Field* (Bloomsbury, 1999)

O'Brien, Cathy: *Trance-Formation of America* (Reality Marketing, 1995)

Scholem, Gershon: *The Messianic Idea in Judaism* (Schocken Books, 1994)

Schwab, Klaus, and Davis, Nicholas: *Shaping the Future of the Fourth Industrial Revolution: A guide to building a better world* (Penguin Books, 2018)

Schwab, Klaus: *The Great Reset* (Agentur Schweiz, 2020)

Sunstein, Cass and Thaler, Richard: *Nudge: Improving Decisions About Health, Wealth, and Happiness* (Penguin, 2009)

Swan, Shanna: *Count Down: How Our Modern World Is Threatening Sperm Counts, Altering Male and Female Reproductive Development and Imperiling the Future of the Human Race* (Scribner, 2021)

Tegmark, Max: *Our Mathematical Universe: My Quest for the Ultimate Nature of Reality* (Penguin, 2015)

Velikovsky, Immanuel: *Worlds in Collision* (Paradigma, 2009)

Wilton, Robert: *The Last Days of the Romanovs* (Blurb, 2018, first published 1920)

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Ickonic is something that has been a dream of mine for the last 5 years, growing up around alternative information I have always had a natural interest in what is going on in the World and what could I do to make it better.
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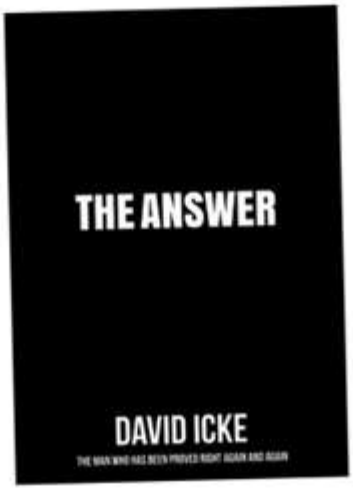
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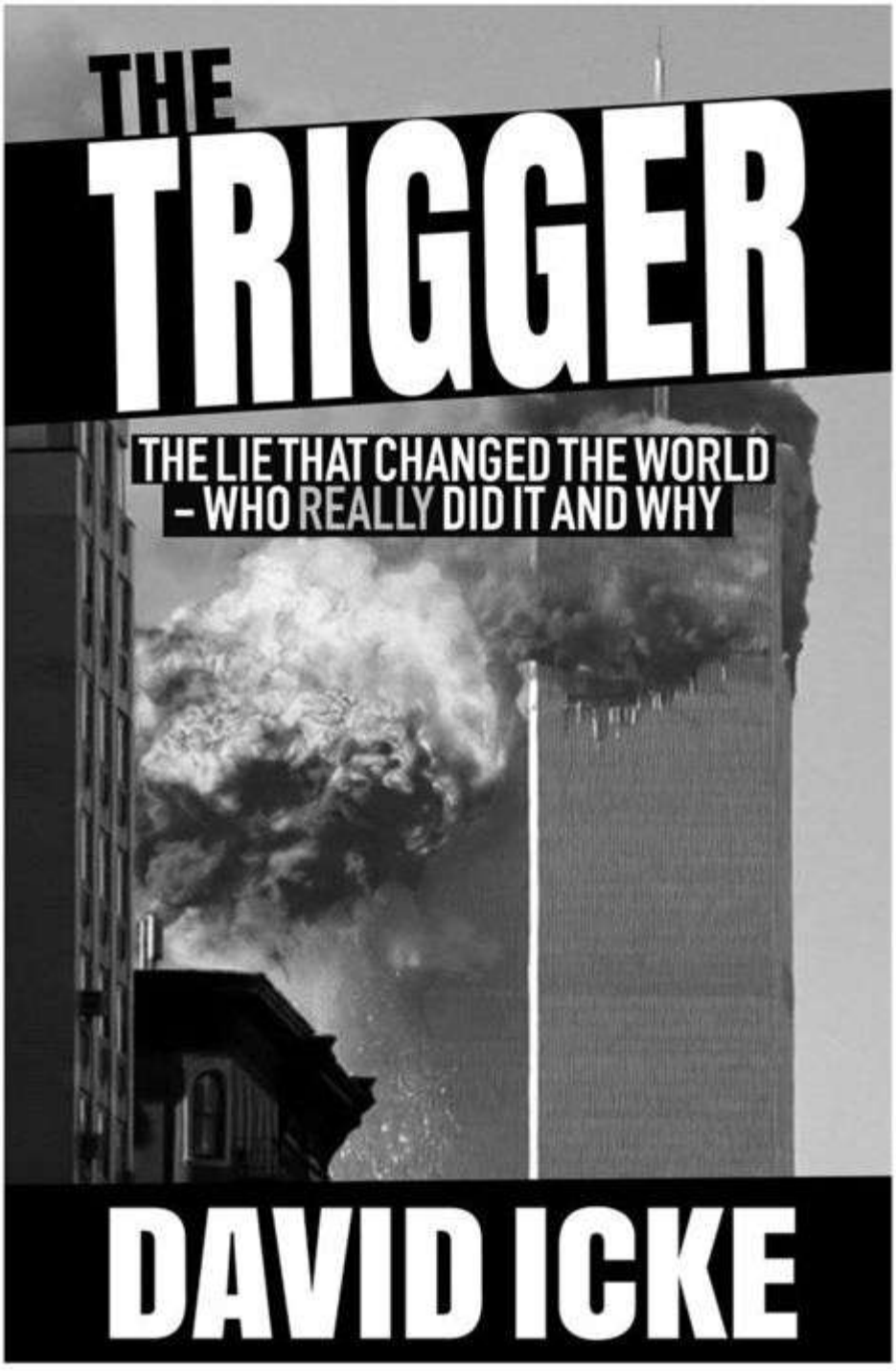
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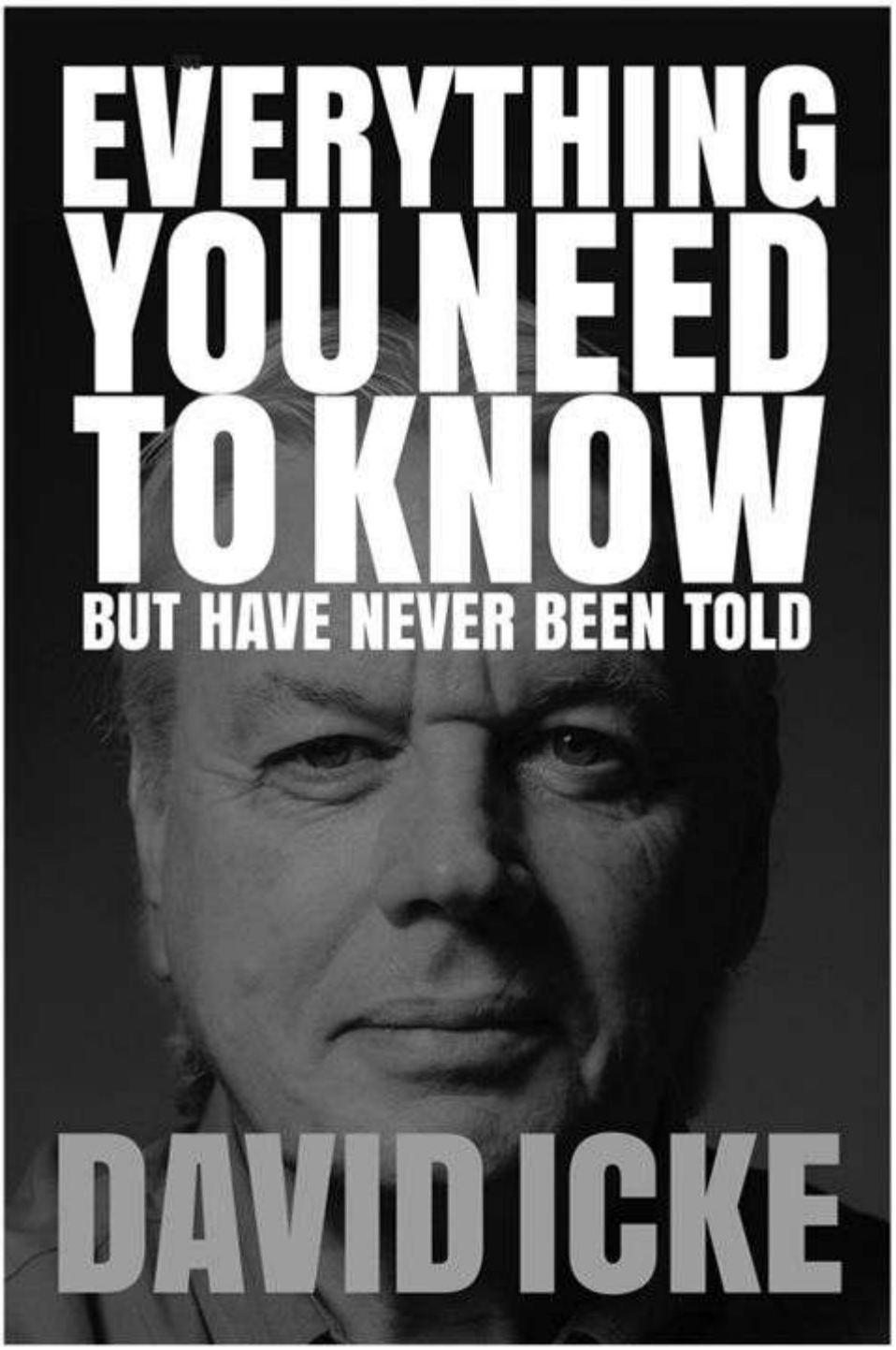


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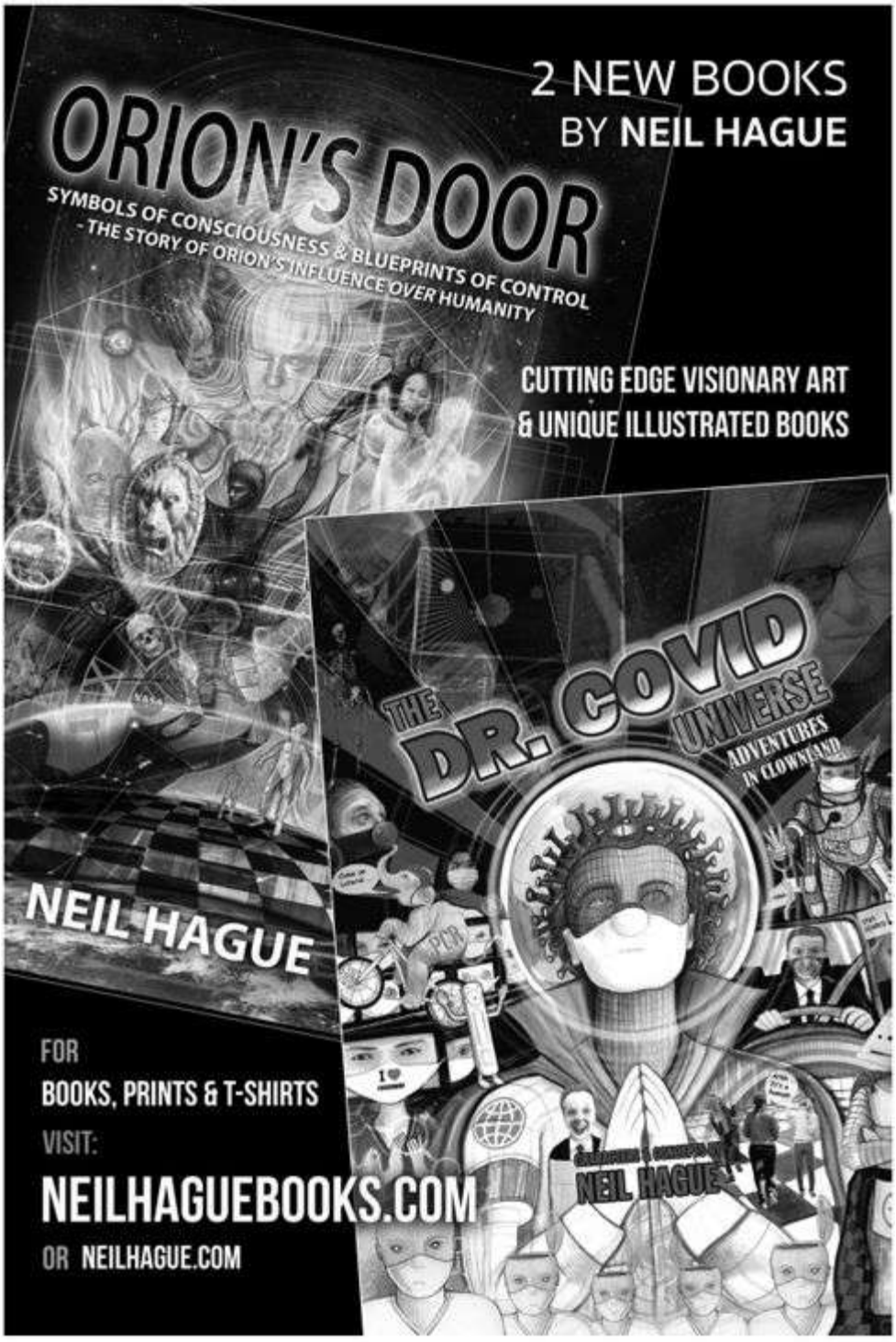
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noun

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