Year 12

Science

SCIENCE

Year 12

GOVERNMENT OF SĀMOA
MINISTRY OF EDUCATION, SPORTS AND CULTURE

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Unit 1

Co-ordinating The Body

Learning outcomes

On completing this unit you should be able to:

- ❑ Define co-ordination
- ❑ Recognise parts of the nervous system
- ❑ Describe the role of the nervous system in co-ordination
- ❑ Recognise parts of the endocrine system
- ❑ Describe the role of the endocrine system in co-ordination

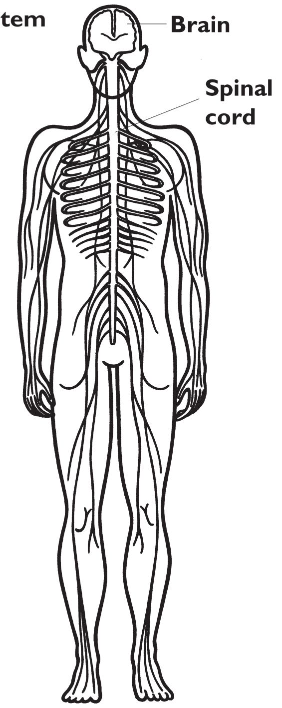
Co-ordinating the body

Co-ordination is the name given to the process in which all body functions are regulated and controlled. Two systems are responsible for co-ordination – the nervous system and the endocrine system.

In the **nervous system**, messages travel as electric currents (impulses) along a nerve fibre (neurone). One nerve fibre usually affects only one muscle or gland cell. The nervous system controls quick acting, short lasting actions, e.g. pulling away the hand from a hot plate.

In the **endocrine system**, messages are sent as chemicals (hormones) that travel around the body in the blood. A hormone is made in an endocrine gland and can affect many parts of the body. The endocrine system controls more long-lasting processes in the body such as metabolic rate and growth.

The Nervous System



The Central Nervous System (CNS) consists of the Brain and the Spinal Cord.

The Peripheral Nervous System (PNS) is a system of nerves that emerge from the spinal cord.

Figure 1.1 Nervous system

The nervous system – quick control

There are three main types of nerve cell or neurone.

- ❑ **Sensory neurones** carry information to the brain. They start in a sensory receptor (eye, ear, nose, tongue, skin) and carry messages to the brain that allow us to see, hear, smell, taste and touch.
- ❑ **Motor neurones** carry information from the brain to the effector organs. An **effector organ** is any organ that has an effect; it could be a muscle contracting to move your arm, a muscle squeezing saliva out of your salivary gland or even an endocrine gland squirting a hormone into your blood.

- ☐ **Relay neurones** are the link between sensory neurones and motor neurones in the Central Nervous System.

Neurones do not touch each other. There is a small gap between them called a **synapse**.

A reflex arc

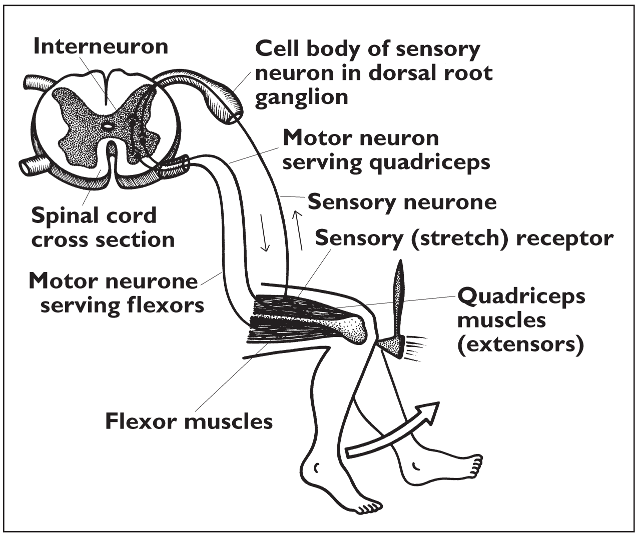


Figure 1.2 Reflex arc

A **reflex arc** is a nerve pathway that produces a fast, simple automatic response when it is stimulated. A doctor tests your reflexes by tapping your leg below the knee. The lower leg swings forward. This is inbuilt or automatic behaviour, and we all behave in the same way.

The **stimulus** is what you feel when the doctor taps you. This sends a message (an impulse) along a sensory neurone to the spinal cord. Here the impulse is carried along a relay neurone, which passes it to a motor neurone. The motor neurone carries the impulse to the effector (in this case, a muscle that straightens the leg).

The endocrine system – slow control

The **hypothalamus**. Nerve cells in the hypothalamus control the pituitary gland by producing chemicals that either stimulate or suppress hormone secretions from the pituitary.

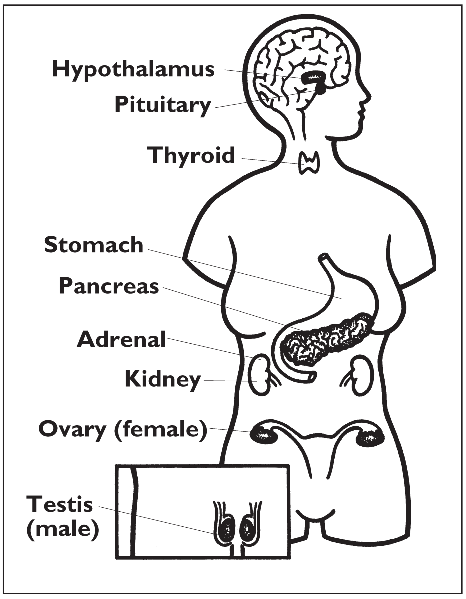


Figure 1.3 The endocrine system

The **pituitary gland** is often called the 'master gland' because it makes hormones that control several other endocrine glands.

The **thyroid gland** controls the rate at which cells burn food to produce energy.

The **adrenal glands** have two parts. The outer part, the adrenal cortex, produces hormones called **corticosteroids** that regulate salt and water balance in the body, the body's response to stress, metabolism, the immune system and sexual function. The inner part, the adrenal medulla, produces **adrenaline** that increases blood pressure and heart rate when the body experiences stress.

The **testes** in the male secrete a hormone called **testosterone** that regulates body changes associated with sexual development, including the height growth spurt, and the appearance of other male secondary sex characteristics such as deepening of the voice, growth of facial and pubic hair, and the increase in muscle growth and strength.

The **ovaries** in the female produce eggs and secrete the hormones **oestrogen** and **progesterone**. These hormones control the development of female sexual features such as breast growth, the accumulation of body fat around the hips and thighs, and the height growth spurt during puberty. These hormones are also involved in pregnancy and the regulation of menstruation.

The **pancreas** produces **insulin** and **glucagon**. They work together with the liver to maintain a steady level of glucose, or sugar, in the blood and to keep the body supplied with fuel to produce and maintain stores of energy.

A hormone in action – adrenaline

In a dangerous situation our brain says, 'Get ready for action.' A signal goes to the **adrenal gland** on top of the kidney.

The adrenal gland releases **adrenaline** to get the body ready for action.

Adrenaline heads for the brain to keep it awake and alert.

Adrenaline causes the heart to pump harder so blood can get to every part that will need to act.

Adrenaline heads for the muscles so they can tense up ready to move. Adrenaline heads for the stomach so it can more quickly digest food for the increased energy that will be required to act.

Blood is removed from the extremities so it can be reassigned to needed organs.

Now vital organs are on high alert so the threat can be met. Our body is ready for 'fight or flight'.

When the danger has passed, high alert is called off, adrenaline levels go down and the body rests.

Activity 1

1 Using the words given, fill the gaps in the following passage with the corresponding letter **a**–**e**.

motor neurone	transmitter	sensory
effector organ	sensory neurone	

When Mika was cooking, he accidentally touched the top of the oven. He immediately pulled his hand away. The (**a**) ______________ organs in his hand detected the heat of the oven. A nerve impulse travelled along a (**b**) ______________ to his spine and through a relay neurone. A chemical (**c**) ______________ stimulated a (**d**) ______________ to send an impulse to the (**e**) ______________ in his upper arm. When it contracted, his hand was pulled away from the oven. Intermediate neurones carried messages to the pain centre of the brain and Mika said 'Okaoka' or something like that.

2 Match the following statements with the words below.

the ear	a gland	an automatic response
a synapse		

a A reflex arc results in . . .

b Sound is sensed by . . .

c An effector organ could be a muscle or . . .

d The gap between two nerves is called . . .

3 Put the following sentences in the appropriate column of the table that follows.

The message travels in the form of a chemical (hormone).
The message travels as an electric current (impulse).
The message travels along a neurone.
The message travels in the blood.
A hormone can affect many cells in the body.
This system regulates longer lasting processes in the body.
Usually affects only one muscle or gland.
This system controls short lasting actions.
Blood sugar level is controlled by this system.
Growth is controlled by this system.
Sneezing is activated by this system.
Vomiting is activated by this system.

Nervous System	Endocrine System

4 Copy and complete the following sentences using the words in the box on the left.

- the 'fight or flight' reaction
- regulate salt balance in the body
- endocrine glands
- the pancreas
- switch the secretion of a hormone on
- the adrenal glands
- the liver
- testosterone
- oestrogen
- the pituitary

a Adrenaline is secreted by . . .
b Chemical messengers are produced by . . .
c Insulin affects . . .
d Adrenalin produces . . .
e Corticosteroids . . .
f The master gland . . .
g One of the female hormones is . . .
h A stimulus can . . .
i The testes can produce a hormone called . . .
j Insulin is produced in . . .

5 Read the passage below than answer the questions that follow.

Hormone action

Once a hormone is secreted, it travels from the endocrine gland through the bloodstream to its target cells. Along the way, special proteins bind to some of the hormones, acting as carriers that control the amount of hormone that is available to interact with and affect the target cells. Also, the target cells have receptors that attract only specific hormones, and each hormone has its own receptor, so that each hormone will communicate only with specific cells that possess receptors for that hormone. When the hormone reaches its target cell, it locks on to the cell's specific receptors and these hormone-receptor combinations transmit chemical instructions to the inner workings of the cell.

When hormone levels reach a certain normal or necessary amount, further secretion is controlled by important body mechanisms to maintain that level of hormone in the blood. This regulation of hormone secretion may involve the hormone itself or another substance in the blood related to the hormone. For example, if the thyroid gland has secreted adequate amounts of thyroid hormones into the blood, the pituitary gland senses the normal levels of thyroid hormone in the bloodstream and gears down its release of thyrotropin, the pituitary hormone that stimulates the thyroid gland to produce thyroid hormones. Parathyroid hormone increases the level of calcium in the blood. When the blood calcium level rises, the parathyroid glands sense the change and decrease their secretion of parathyroid hormone. This turn-off process is called a 'negative feedback' system.

a What controls the amount of hormone in the blood?
b What happens when a hormone reaches the target cells?
c What is thyrotropin?
d Explain the term 'negative feedback system'.

Unit 2

Maintaining The Body

Learning outcomes

On completing this unit you should be able to:

- ❑ Recognise the structures that make up the immune system
- ❑ Describe how the body fights infection
- ❑ Define homeostasis
- ❑ Describe how the body maintains internal balance

Immune system

Microscopic living things, such as bacteria and viruses, get on to our skin, into the food we eat, into the drinks we consume and even into the air we breathe. They may also get into our body through a cut or wound. If enough germs get into the body, they can start to multiply and cause problems. This is an infection.

The body has several sets of defences against germs. These include the skin, the moist germ-trapping linings of the breathing and digestive passageways, the way blood clots to seal wounds and leaks, white cells and other substances in the blood, the thymus gland in the chest and small lymph nodes or glands spread all over the body. Together, all these parts form the body's immune defence system.

The body's immune system includes several kinds of white cells in blood, body fluids and **lymph nodes**. These white cells attack any germs that are in the body.

When the body is ill with an infection, various glands swell up. Many of these are lymph nodes. When you are healthy they are about the size of a pea or grape, but during illness they can be as big as golf balls.

Lymph nodes contain billions of white cells, multiplying rapidly to fight the invading germs. During illness they fill with millions of extra white cells and also dead germs.

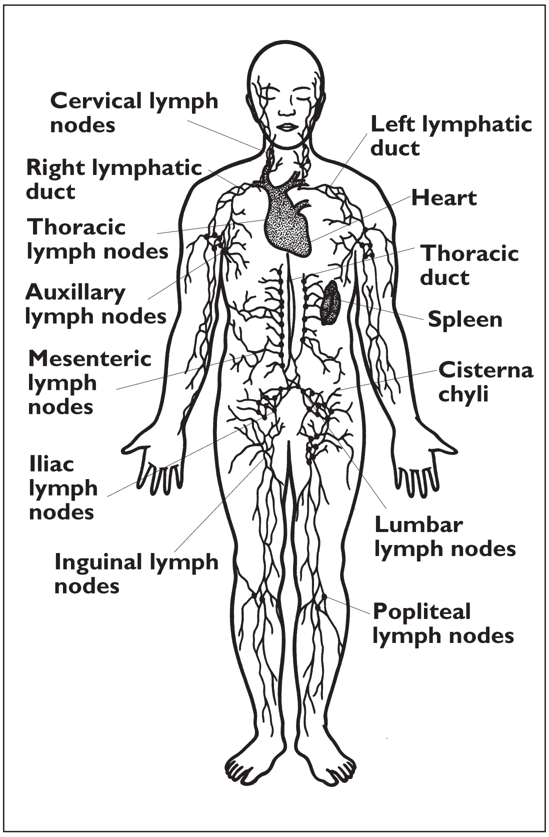


Figure 2.1 Immune system

Stopping germs getting into the body

A wound or cut in the skin leaks blood from the damaged blood vessels.

1. Chemicals released from damaged cells and platelets make dissolved substances in the blood turn into a meshwork of microfibres of the substance fibrin.

This network traps blood cells.

2. Gradually the meshwork hardens into a clump or clot that seals the leak.

The clot then hardens and dries further into a protective scab.

3. White cells arrive to attack any germs, and the skin begins to regrow and heal.

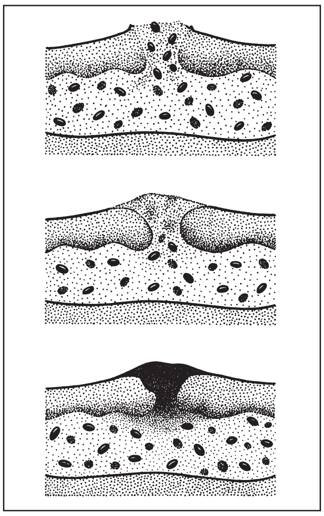


Figure 2.2 Stopping germs getting into the body

Fighting germs inside the body

Tonsils and adenoids

The tonsils are patches of lymph tissue at the upper rear part of the throat. They help to destroy foreign substances that are breathed in or swallowed. The adenoids are similar patches at the rear of the nasal cavity in the nose.

Thymus

The thymus gland in the front of the chest is large during childhood, but shrinks away during adulthood. It helps certain white cells of the immune system to develop and play their part in the body's defences.

Spleen

The spleen is just behind the stomach on the left side. It makes and stores various kinds of white cells, especially the *phagocytes* that 'eat' germs. It also makes and stores red cells for the blood, and generally cleans and filters blood.

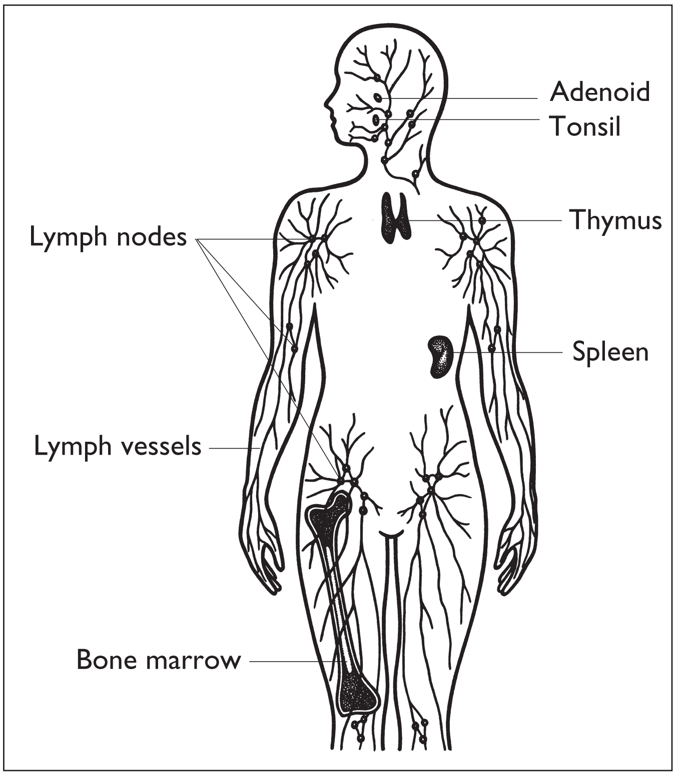


Figure 2.3 Fighting germs inside the body

Homeostasis

Homeostasis means keeping the internal body conditions constant. Internal conditions that are controlled include water content, temperature and blood sugar levels.

Maintaining water balance

The kidneys help to maintain the internal environment by:

- ❑ First **filtering** the blood.
- ❑ Reabsorbing all the **sugar**.
- ❑ Reabsorbing the dissolved **ions** needed by the body.
- ❑ Reabsorbing as much water as the body needs.
- ❑ Releasing urea, excess ions and excess water as urine.

The kidneys produce dilute urine if there is too much water in the blood or concentrated urine if there is too little water in the blood.

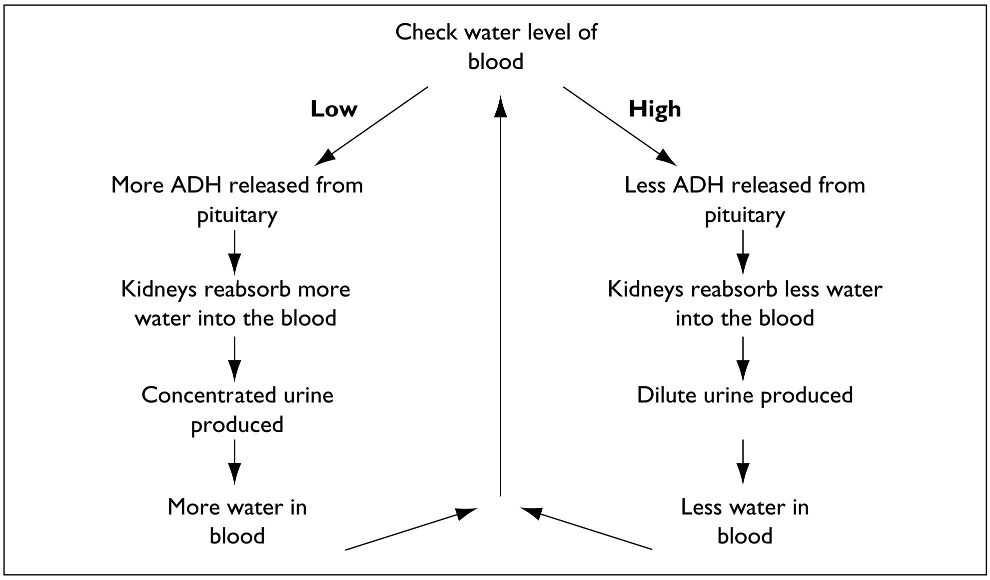


Figure 2.4 Homeostasis

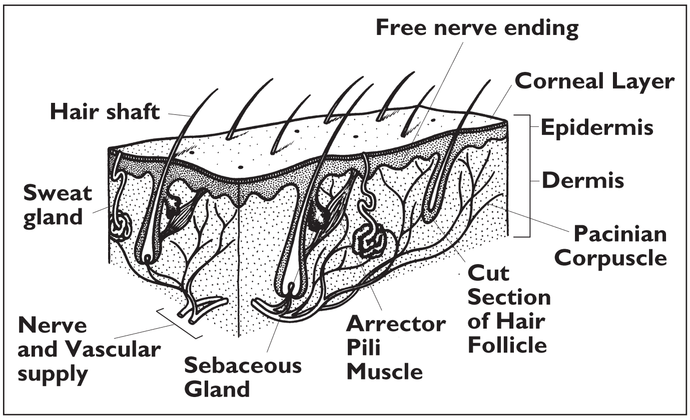


Figure 2.5 Cross-section of skin

If the water content of the blood is too low, the pituitary gland releases a hormone called ADH into the blood. This causes the kidneys to reabsorb more water and results in a more concentrated urine.

If the water content of the blood is too high, less ADH is released into the blood. Less water is reabsorbed in the kidneys resulting in a more dilute urine.

Maintaining a steady temperature

Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has receptors sensitive to the temperature of blood flowing through the brain. Also temperature receptors in the skin send impulses to the centre giving information about skin temperature.

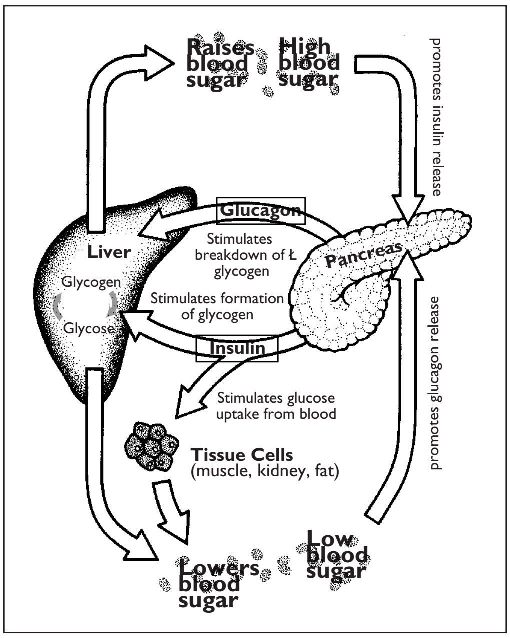


Figure 2.6 Maintaining blood sugar levels

If the core body temperature is too high, blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost. Sweat glands release more sweat which evaporates to cool the body.

If the core body temperature is too low, blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries. Muscles may 'shiver' – their contraction involves respiration that releases some energy as heat.

Maintaining blood sugar levels

The pancreas is an endocrine gland that produces hormones that regulate blood glucose (sugar) levels. An **increase** in blood sugar level triggers the release of the hormone **insulin** by the pancreas. Insulin lowers blood sugar level restoring the body to its original blood sugar level in two major ways. Firstly, it increases the ability of body cells to take in glucose from the blood and secondly, it converts blood glucose to the compound **glycogen** – this compound is also called animal starch and is stored in our liver and muscles. People who cannot make insulin are diabetic.

Activity 1

1 Match up the terms with the definitions.

a	clot	**A**	causes blood to clot
b	fibrin	**B**	contain millions of white blood cells
c	homeostasis	**C**	destroy germs breathed in
d	immune	**D**	helps white blood cells to develop
e	lymph nodes	**E**	maintaining a steady state in the body
f	mucus	**F**	protected from disease
g	phagocytes	**G**	seals blood leaking from a wound
h	spleen	**H**	stores white blood cells
i	thymus	**I**	traps germs in nose and lungs
j	tonsils	**J**	white blood cells that eat germs

2 Some words are missing from the passage below. Choose the correct words from the list, then copy and complete the following paragraphs in your book.

lower
raised
shivering
homeostasis
thermoregulating

It was a really hot day and waiting outside the examination hall I could feel the sweat forming on my skin. I had revised this topic last month and knew that I was (**a**) __________. The teacher had turned the fans on so I expected the sweat to evaporate; this would (**b**) __________ my body temperature. I knew that there might be an exam question about controlling my internal conditions: the word (**c**) __________ was on the tip of my tongue and then it came to me! When I was (**d**) __________ in New Zealand during winter, my muscles had (**e**) __________ my body temperature by doing this. It was then that I knew I was going to get top marks for science.

3 Answer these questions.

a Name the process of keeping internal conditions constant.

b Name the process of keeping a constant body temperature.

c Which hormone is used to reduce the amount of glucose in the blood?

d Which cellular process requires glucose?

e Our cells might swell or burst if there was too much __________ in our blood.

4 Explain how your body temperature is controlled on a very hot day.

5 Read the passage then answer the questions that follow.

How antibiotics work

Sometimes your immune system is not able to activate itself quickly enough to outpace the reproductive rate of a certain bacteria, or the bacteria is producing a toxin so quickly that it will cause permanent damage before the immune system can eliminate the bacteria. In these cases it would be nice to help the immune system by killing the offending bacteria directly.

Antibiotics work on bacterial infections. Antibiotics are chemicals that kill the bacteria cells but do not affect the cells that make up your body. For example, many antibiotics interrupt the machinery inside bacterial cells that builds the cell wall. Human cells do not contain this machinery, so they are unaffected. Different antibiotics work on different parts of bacterial machinery, so each one is more or less effective on specific types of bacteria. You can see that, because a virus is not alive, antibiotics have no effect on a virus.

One problem with antibiotics is that they lose effectiveness over time. If you take an antibiotic, it will normally kill all of the bacteria it targets over the course of a week or 10 days. You will feel better very quickly (in just a day or two) because the antibiotic kills the majority of the targeted bacteria very quickly. However, on occasion one of the bacterial offspring will contain a mutation that is able to survive the specific antibiotic. This bacteria will then reproduce and the whole disease mutates. Eventually the new strain is infecting everyone and the old antibiotic has no effect on it. This process has become more and more of a problem over time and has become a significant concern in the medical community.

a Describe how antibiotics work.
b Why are human cells not usually affected by antibiotics?
c Why do antibiotics not work on viruses?
d Why do some antibiotics lose their effectiveness over time?

6 Set out below are the steps involved in the blood clotting process. Put them in the right order.

a Chemicals released from damaged cells produce a net of fibrin.
b The clot then hardens and dries further into a protective scab.
c White cells arrive to attack any germs, and the skin begins to regrow and heal.
d The meshwork hardens into a clump or clot that seals the leak.
e The skin leaks blood from the damaged blood vessels.
f This network traps blood cells.

7 Identify the parts of the immune system in this diagram.

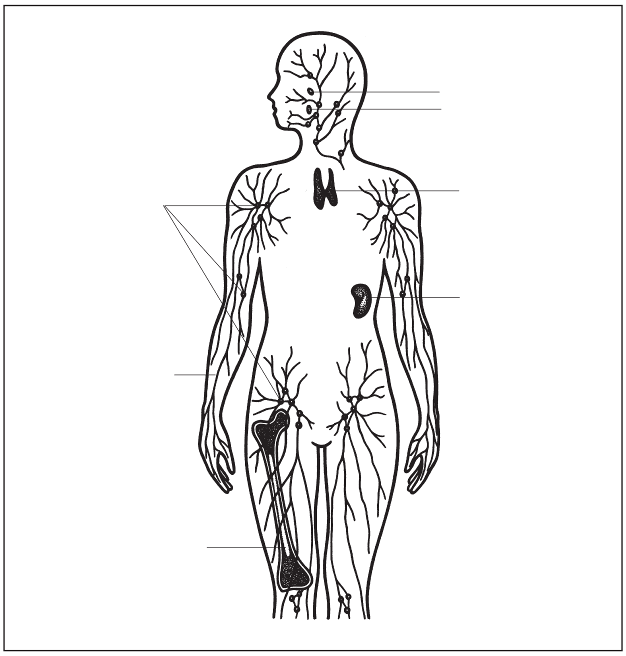


Figure 2.7 Immune system

Unit 3

Plant And Animal Cells

Learning outcomes

On completing this unit you should be able to:

- Identify the parts of a light microscope
- Use a light microscope to view slides
- Prepare slides for viewing under a light microscope
- Identify cells and tissues on slides

The light microscope

A light microscope has the following basic systems:

Specimen control – to hold the slides

- **stage** – where the slide sits
- **clips** – used to hold the slide on the stage

Illumination – to shine light on the slide (the simplest illumination system is a mirror that reflects room light up through the specimen)

- **lamp** – some microscopes have a light bulb to produce the light
- **condenser** – some microscopes have a lens system that aligns and focuses the light from the lamp on to the specimen
- **diaphragms or pinhole apertures** – placed in the light path to alter the amount of light that reaches the condenser (for enhancing contrast in the image)

Lenses – to form the image

- **objective lens** – (near the object). It gathers light from the slide
- **eyepiece** – transmits and magnifies the image from the objective lens to your eye
- **nosepiece** – rotating mount that holds many objective lenses
- **tube** – holds the eyepiece at the proper distance from the objective lens and blocks out stray light

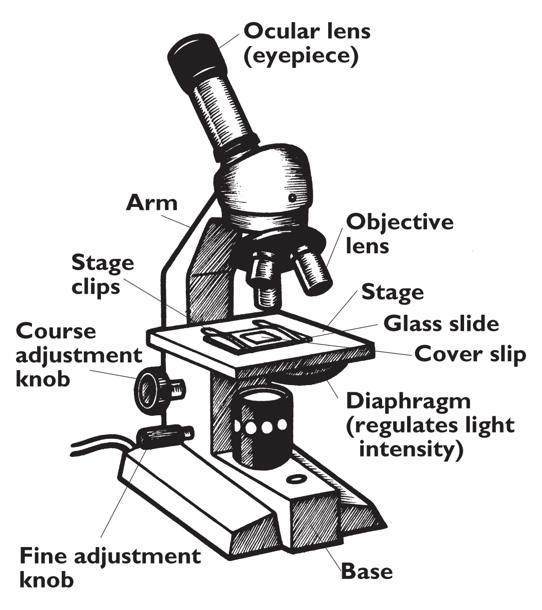


Figure 3.1 Light microscope

Focus – to position the objective lens at the proper distance from the specimen

- ❑ **coarse-focus knob** – used to bring the object into the focal plane of the objective lens
- ❑ **fine-focus knob** – used to make fine adjustments to focus the image

Support and alignment

- ❑ **arm** – curved portion that holds all of the optical parts at a fixed distance and aligns them
- ❑ **base** – supports the weight of all of the microscope parts

Focusing the microscope

- ❑ Place the slide on the stage.
- ❑ Make sure the **low power objective** (the shortest objective lens) is in position.
- ❑ Turn the **coarse focus** until the lens is at a position closest to the stage.
- ❑ Set the diaphragm to its largest opening (where it allows the most light through).
- ❑ Look through the **ocular lens** and begin to slowly turn the coarse focus.
- ❑ When the specimen is focused under low power, move the slide so that what you want to see is in the middle of the field of view.
- ❑ Switch to a higher power objective.
- ❑ DO NOT touch the coarse focus again – you will break something! Once you are using a high power objective, focus using the fine focus knob ONLY.

Preparing slides

There are two different types of microscope slides used. The common flat glass slide, and the depression or well slide. Depression slides have a round dip in the centre to hold a drop of liquid. They are usually used without a cover slip.

A cover slip is a very thin square piece of glass that is placed over the water drop on a flat slide. The cover glass helps to reduce the amount of focusing necessary. It also protects the objective lens from dipping into the water drop.

When preparing a well slide, transfer one to four drops from the sample container to the depression slide. Focus carefully and do not use the higher power objective lenses as they will likely get wet when focusing too close to the drop.

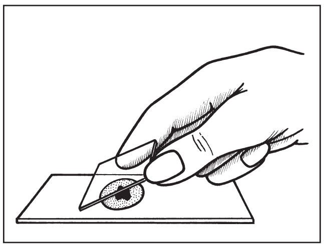


Figure 3.2 Wet mount slide preparation

The most common slide preparation is called the 'wet mount' slide – a flat slide and a cover slip. Place a drop of the sample in the middle of a clean slide and lower a cover slip gently over the drop at an angle, with one edge touching the slide first. Allow the liquid to spread out between the two pieces of glass without applying pressure. If you do not place a large enough sample it may dry out. If you place too large a sample the cover slip will float away.

Stains are used to allow parts of cells to be seen more easily. Iodine, methylene blue or crystal violet may be added to specimens in order to increase contrast. The stain can be directly added to the water when first preparing the slide, or it can be added later after first viewing the specimen without the stain. Add a drop of the stain along one edge of the cover slip. Placing a piece of paper towel along the opposite edge of the cover slip will help draw the stain under the cover slip.

Cells and tissues

Both animal and plant cells contain proper nuclei with chromosomes and **cytoplasm**. Perhaps the most important things to be found in cytoplasm are **mitochondria**. A mitochondrion contains all the enzymes needed to obtain energy from glucose. They can only be seen with an electron microscope. Animal and plant cells also have a cell membrane around them. **Cell membranes** are very thin, but they are able to control what can get in or out of a cell.

Plant cells are surrounded by a **cell wall** made of cellulose. The cell wall is NOT living. Plant cells also contain **chloroplasts**. These contain a green chemical called **chlorophyll**. Chlorophyll is necessary for photosynthesis. Animal cells never contain **chloroplasts**. Most of the space inside a plant cell is filled with cell sap in a large **vacuole**. Animal cells never contain large vacuoles. Plant cells usually have a very regular shape, whereas animal cells usually have very irregular shapes.

A large group of cells that are similar in appearance and function are known as tissues. The human body has four groups of tissue: **epithelial tissue** (covering tissue such as skin), **connective tissue** (joining tissue such as ligaments and tendons), **muscle tissue** and **nerve tissue**. Plants have three types of tissue: **dermal tissue** (a covering or skin tissue), **ground tissue** (the main part of the plant) and **vascular tissue** (tissue that transports water and starch around the plant).

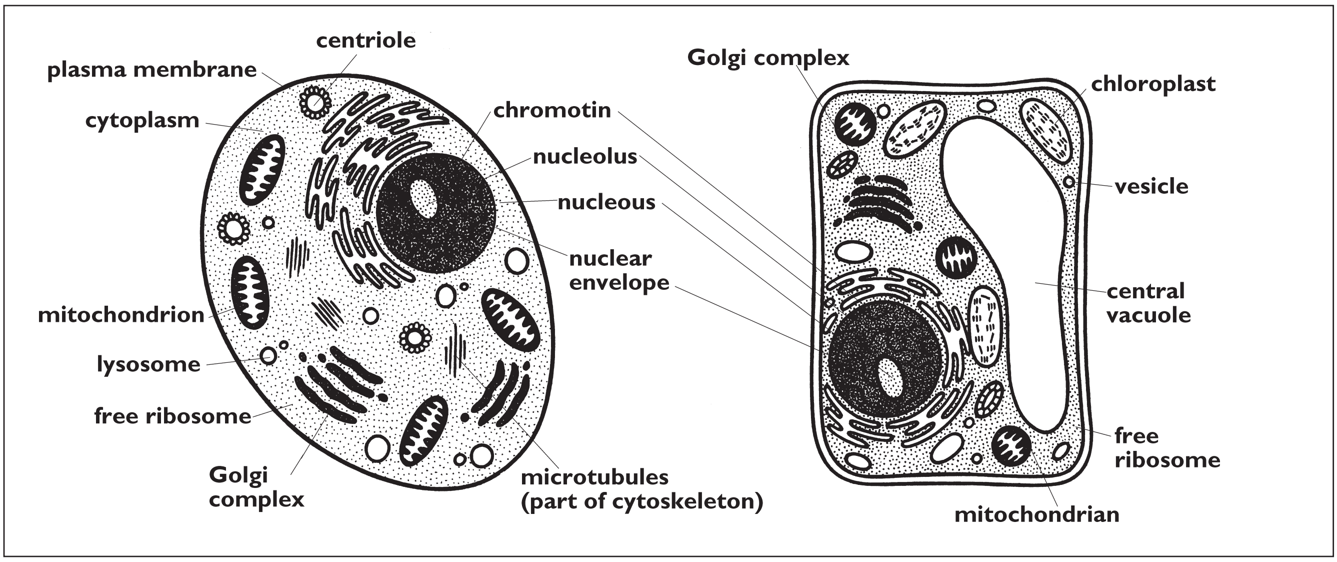
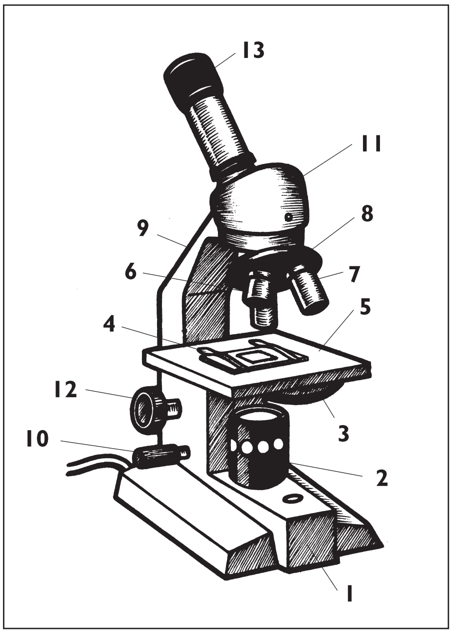


Figure 3.3a A typical animal cell, and Figure 3.3b A typical plant cell

Activity 1



1 Match the names in the word bank with the numbered parts in the picture.

a arm
b base
c body tube
d coarse focus knob
e diaphragm
f fine focus knob
g high power objective lens
h light source
i low power objective lens
j nosepiece
k ocular (eyepiece)
l stage
m stage clips

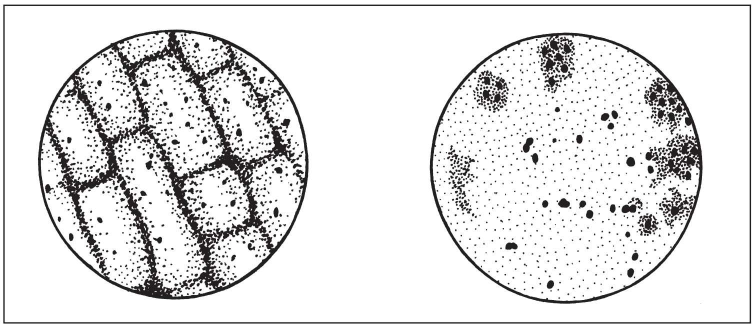
2 A student wrote out the following instructions for viewing a slide on the microscope but got them mixed up. Put them in the right order.

a Use the **coarse focus** to lower the lens until it is close to the slide.
b Focus using the fine focus knob.
c Look down the eyepiece.
d Move the slide so that the object is in the middle.
e Open the diaphragm.
f Put the slide on the stage.
g Select a higher power objective.
h Select the **low power objective**.

3 Answer the following questions about preparing microscope slides.

a When would you use a depression microscope slide rather than a flat slide?
b Give two reasons why a cover slip is used.
c Why should you not use the high power objective lens when first focusing?
d What might happen if you do not use enough liquid for a wet mount slide?
e What might happen if you use too much liquid for a wet mount slide?
f Why is a stain sometimes used in the preparation of microscope slides?

4 The following pictures show what is seen through a microscope when looking at two different slides. Identify which one shows plant cells and which one shows animal cells. Give reasons for your answers.



A **B**

Unit 4

Chromosomes, Genes And DNA

Learning outcomes

On completing this unit you should be able to:

- ☐ Explain why zygotes can grow into completely different organisms
- ☐ Describe the structure of DNA and define the nature of a gene
- ☐ Explain how the genetic code works
- ☐ Outline how chromosomes are duplicated in the process of mitosis
- ☐ Explain how gametes get half the chromosomes of body cells

Zygotes and chromosomes

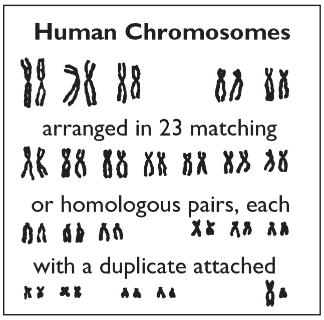


Figure 4.1 Human chromosomes

Life begins as a single-celled **zygote** formed when a sperm fertilises an egg. The zygotes of humans, chimps and horses all look the same yet they develop into different organisms. Why?

The zygote **nucleus** contains many **chromosomes**, each of which consists of several thousand **genes**.

The total collection of genes in the zygote is called the organism's **genome**. The genome specifies what species the organism will be and its particular **traits**.

Chromosomes are very long, thin thread-like structures that are able to coil up tightly into short, fat shapes. Chromosomes in this state are visible under the microscope as cells divide.

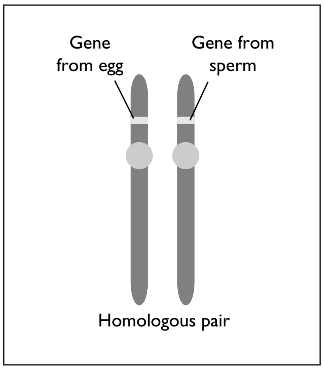


Figure 4.2 Homologous pair

All members of a **species** have the same number of chromosomes at the zygote stage and it will be an even number, e.g. human zygotes normally have 46, chimp zygotes 48 and horse zygotes 64.

The chromosomes in a zygote vary in size and shape, but they can be arranged into matching pairs based on the length of the chromosome and where duplicates are attached to each other (see figure 4.1). Human zygotes have 23 matching pairs. These matching pairs are called **homologous chromosomes**. One member of each pair will have come from an egg and the other from a sperm. Human egg and sperm have 23 each.

Usually you inherit two genes for each trait – one gene from each parent. If one of those genes is at a site on a particular chromosome, then the other gene will be found at the same site on the other homologous chromosome.

Chromosomes and genes

Chromosomes are complex structures made of molecules of deoxyribonucleic acid (or **DNA** for short). How does DNA carry genetic information?

Each chromosome consists of two long DNA molecules. Each DNA molecule has millions of chemicals called **bases** attached at regular intervals along its length. There are only four types of bases, which are called C, G, A and T for short.

The two DNA molecules are joined together to form a ladder-like structure with millions of rungs. Each rung of the ladder is formed by a pair of bases – a base on one strand is attracted to a base on the other. But C bases only fit with G bases, and A bases only with T bases.

The scientists Watson and Crick discovered that the ladder structure is twisted into a helix. As there are two DNA molecules involved they called this structure the **double helix**.

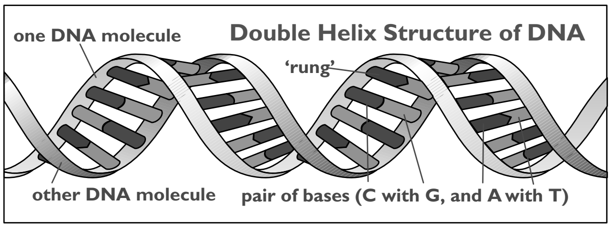


Figure 4.3 Double helix structure of DNA

Along each DNA molecule is a sequence of over a million bases, e.g. ATTCCGATGGACTCGGAATCTCTT . . . Watson and Crick proposed that a gene was actually a length of DNA several thousand bases long.

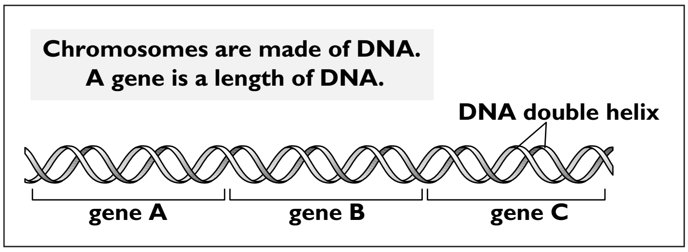


Figure 4.4 DNA double helix

Next, they proposed that the information carried by a gene is encoded in the sequence of bases along a section of one of the DNA molecules. The **genetic code** uses an 'alphabet' of just four bases which are arranged in triplets, e.g. ATT-CCG-ATG-GAC-TCG-GAA-TCT-CTT- . . .

The unique sequence of bases that make up a particular gene determines the structure of a unique **protein**. That protein is then involved in determining the appearance of a particular trait. Each of the 80 000 plus genes in your genome determines a different protein, which in turn determines the appearance of a particular trait (e.g. your hair or eye colour).

A gene codes for a protein that determines a trait.

Copying chromosomes

A new organism grows from a single-celled zygote to an adult organism by **mitosis**. One cell divides into two, two divide to give four, four divide to give eight and so on. Eventually, the adult organism consists of billions of body cells, each with an identical set of chromosomes (e.g. human body cells all have 46).

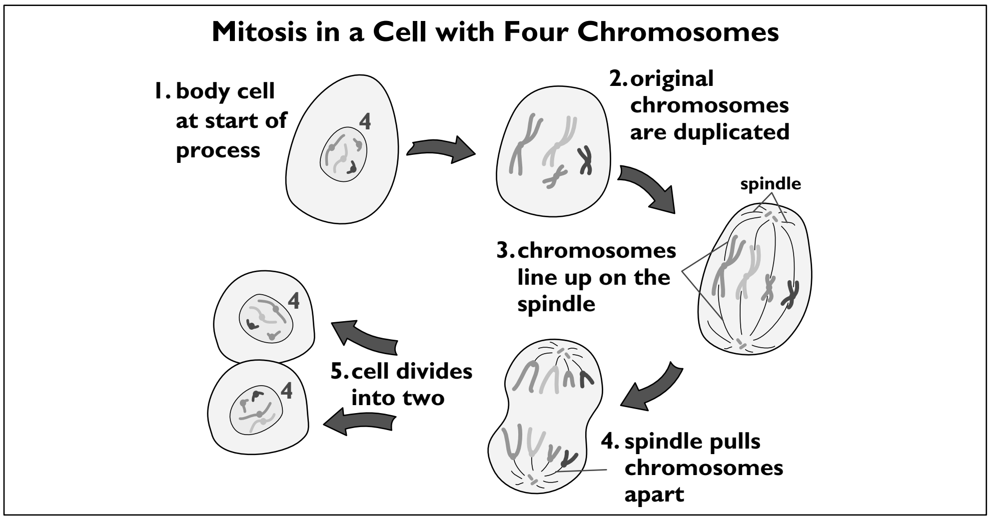


Figure 4.5 Mitosis in a cell with four chromosomes

Early in mitosis, when chromosomes shorten, each chromosome appears with an identical copy or duplicate attached. As mitosis proceeds, duplicated chromosomes are separated, resulting in each new cell having an identical set. How are the chromosomes duplicated?

One of the two DNA molecules making up a chromosome carries the code for genes in the sequence of its bases. The other molecule carries the 'anti-code' for those genes. When a chromosome is about to be duplicated, the pairs of bases making up the rungs separate and the two DNA molecules unzip to reveal the code and the anti-code strands (see figure 4.6).

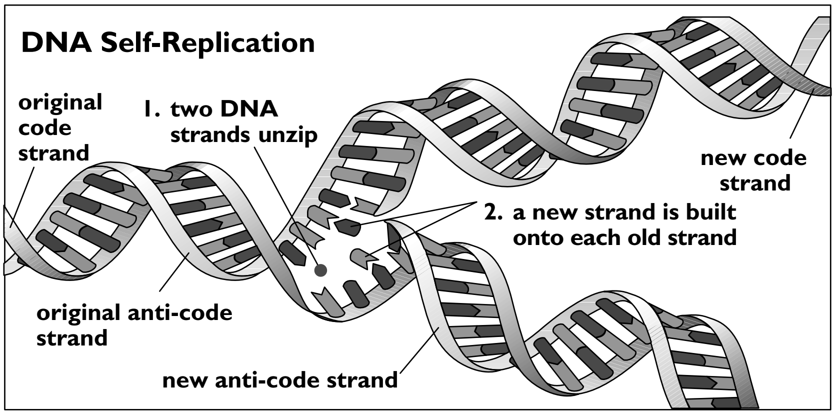


Figure 4.6 DNA self-replication

As the two strands are exposed, a new DNA molecule is immediately built on to each strand. A new anti-code strand is built onto the old code strand, and a new code strand is built onto the old anti-code strand.

By the time the original chromosome is completely unzipped, two new identical chromosomes have already been constructed. Each chromosome in a cell is duplicated – this process is called **replication**.

Mitosis occurs where new body cells are being formed.

Passing on chromosomes

Genes are passed from one generation to another on the chromosomes found inside the **gametes** (egg and sperm). Gametes are formed by the process of **meiosis**, which occurs in a woman's ovaries and a man's testicles. Gametes have half the number of chromosomes that body cells have and each gamete has a different collection of chromosomes. How does meiosis achieve this?

Meiosis consists of two cell divisions that result in four gametes. During meiosis the original cell divides twice but the chromosomes are duplicated only once, so gametes end up with half the normal number of chromosomes. The chromosomes are duplicated early on.

In the first division homologous chromosomes are separated. Initially they are brought together and lengths of chromosomes are swapped. The chromosomes are then pulled apart so that the two new cells get one chromosome from each homologous pair. As members of pairs are randomly separated, each new cell has a different collection of chromosomes.

In the second division the duplicated chromosomes are separated resulting in gametes with only half the number of chromosomes as body cells. As each gamete gets only one chromosome from each homologous pair, a gamete will have only one gene for each trait. But a zygote will have two at fertilisation.

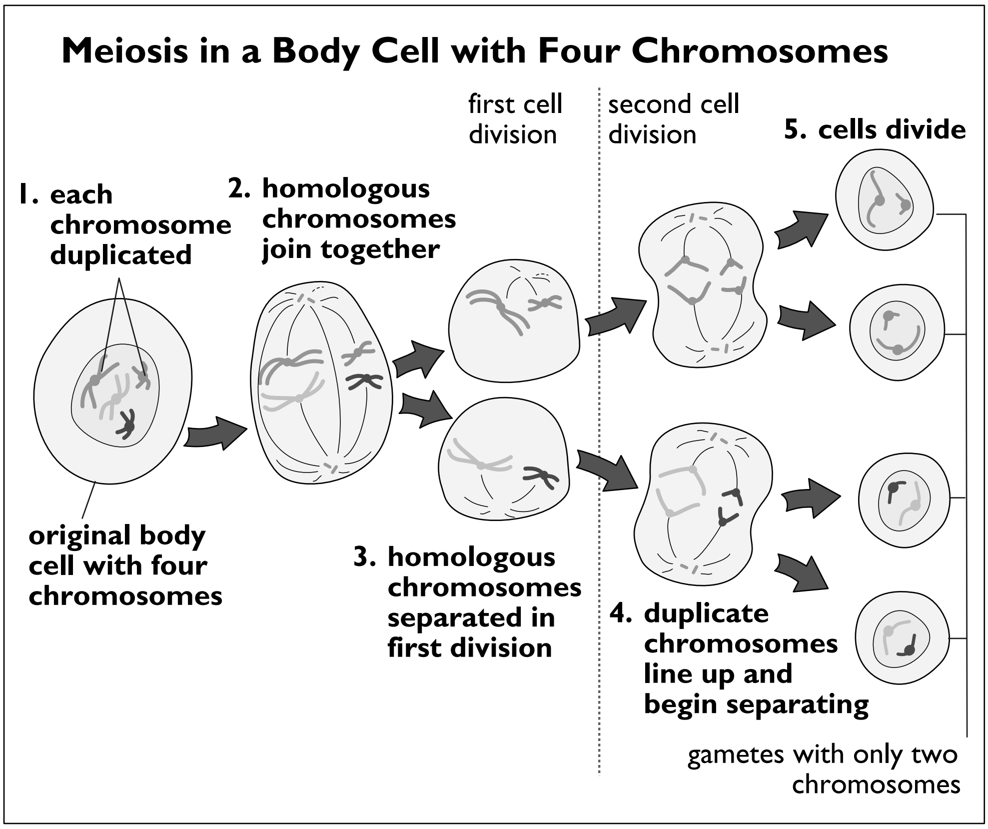


Figure 4.7 Meiosis in a body cell with four chromosomes

Activity 1

1 Match up definitions with terms.

a zygote	**A** the shape that two DNA molecules form together
b nucleus	**B** special sex cells with half the normal number of chromosomes
c chromosomes	**C** total collection of genes possessed by an organism
d gene	**D** the molecules that chromosomes are made out of
e genome	**E** genes are expressed through these molecules
f trait	**F** group of similar organisms able to interbreed successfully
g species	**G** long, thread-like structures that carry the genes
h homologous chromosomes	**H** ability of DNA to make duplicate copies of chromosomes
i DNA	**I** cell division that produces four gametes each with half the normal number of chromosomes
j bases	**J** a pair of chromosomes, one of which came from each parent
k double helix	**K** first cell of an organism after a sperm fertilises an egg
l genetic code	**L** cell division that gives two cells with identical chromosomes
m proteins	**M** feature of an organism that is determined by genes
n mitosis	**N** these form the units of the genetic code
o self-replication	**O** structure within a cell that contains the chromosomes
p gametes	**P** the code that is used to specify information carried by genes
q meiosis	**Q** an inherited object that determines the appearance of a trait

2 For each of these points explain the difference between the terms.

- **a** gene and genome
- **b** identical and homologous chromosomes
- **c** body cells and gametes
- **d** mitosis and meiosis.

3 Copy and complete the table then answer the questions that follow.

Species	**Number of Chromosomes in . . .**			
	Egg	**Sperm**	**Zygote**	**Body Cell**
humans		23		
chimps	24			
horses			64	
dogs				78
cats		19		

a What process ensures that gametes have half the number of chromosomes compared to body cells?

b What process ensures that a zygote has twice as many chromosomes as gametes?

c What process ensures that body cells have the same number of chromosomes as the zygote?

4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

a In sexual reproduction a zygote is the first stage of a new organism.

b Your genome is the complete collection of genes that were in your zygote.

c All species have the same number of chromosomes.

d All members of a species have the same number of chromosomes in each of their body cells.

e Normally you have two genes for each trait, one inherited from each parent.

f Chromosomes are made of DNA and a gene is a length of DNA.

g The genetic code uses an ‘alphabet’ of four bases that are arranged in three-letter ‘words’ called triplets.

h Genes are expressed through proteins that determine the appearance of a trait.

i Chromosomes are duplicated by the process of DNA self-replication.

j Mitosis produces four gametes with half the normal number of chromosomes.

5 The diagram opposite shows the chromosomes in a body cell early on in mitosis cell division. Note that each chromosome has a duplicate attached.

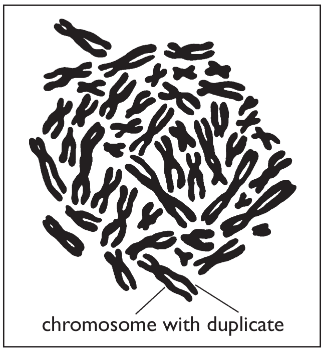
a What type of organism is this body cell likely to come from? How do you know?

b Why have the chromosomes been duplicated?

c How many duplicated chromosomes are there in total?

d What process produced the duplicated chromosomes?

e After cell division, how many chromosomes will each new cell have?



6 The chromosomes in the diagram opposite were cut out and arranged into matching pairs as shown in this diagram.

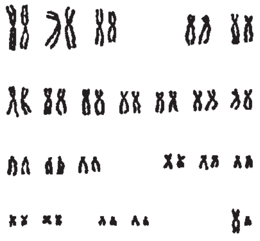
a How many pairs are there?

b What features are used to match up the chromosomes?

c What are these pairs of chromosomes called?

d Where did each member of a pair originally come from?

e Which pair is strange? Why?



7 Label structures **a** to **e**, then answer the questions below.

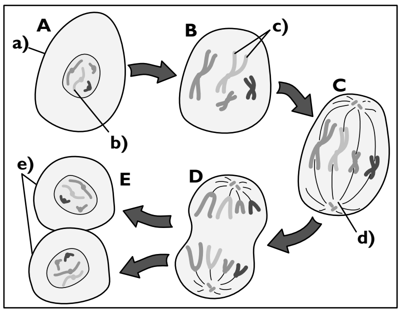
f What type of cell division is shown?

g How do you know?

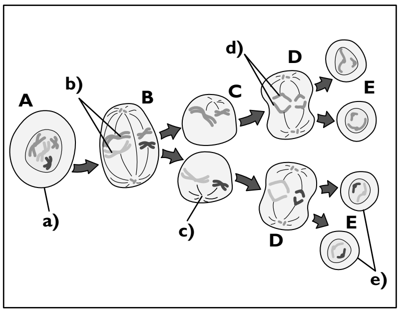
h What has happened to the chromosomes by stage B?

i What is happening to the chromosomes at stages C and D?

j What two statements can be made about the chromosomes in the two cells shown at stage E? (number and nature)



8 Label the structures **a** to **e** in the diagram, then answer the questions below.



- **f** What type of cell division is shown?
- **g** How do you know?
- **h** Where would this process be taking place in male and female animals?
- **i** What has happened to the chromosomes by stage A?
- **j** What is happening to homologous chromosomes in stage B?
- **k** What type of chromosome pairs have separated by stage C?
- **l** What type of chromosome pairs are separating at stage D?
- **m** What two statements can be made about the chromosomes in the four cells shown at stage E compared to the chromosomes in the original cell? (number and nature)
- **n** If this process was occurring in a male, what would the four cells be?

9 Read the passage below, then answer the questions that follow.

The Human Genome Project

The Human Genome Project aimed to identify all of the 30 000 genes that humans possess and to determine the sequence of the three billion base pairs that make up human DNA.

A genome is all the DNA in an organism at the zygote stage. This DNA contains coded information for all the genes, but much of the DNA is redundant and does not code for anything. So sequencing all of the DNA is a more extensive task than identifying the location of the genes.

The DNA is found in the 23 pairs of chromosomes that all human body cells have. Teams of geneticists are involved in sequencing the DNA of different chromosomes or sections of chromosomes.

DNA is made up of four bases (C, G, A and T) that are repeated millions of times in the genome. The order of Cs, Gs, As and Ts is important. It dictates whether an organism is human or another species.

As each person's genome is unique (except for identical twins) and samples from different people will be used, the reference genome will not be an exact match for any one person's genome. Geneticists estimate that we differ in about 0.1% of our three billion base pairs.

Genes are lengths of DNA several thousand bases long and they code for all the proteins in the body. These proteins determine the structure, appearance and functioning of our bodies.

Scientists isolate a protein and from its composition they identify the sequence of bases of the gene. They then identify which chromosome carries that sequence and whereabouts along that chromosome the sequence is. Given that each chromosome is millions of bases long this is a difficult task.

The first stage of the Human Genome Project, which was to determine the sequence of the 3 billion base pairs that make up human DNA, was completed in June 2000.

a What are the two aims of the project?

b If we have about 30 000 genes and 23 distinct chromosomes, on average how many genes will a chromosome carry?

c If there are 3 000 000 000 base pairs in the genome – on average how many base pairs long will a chromosome be?

d What units are used in the genetic code?

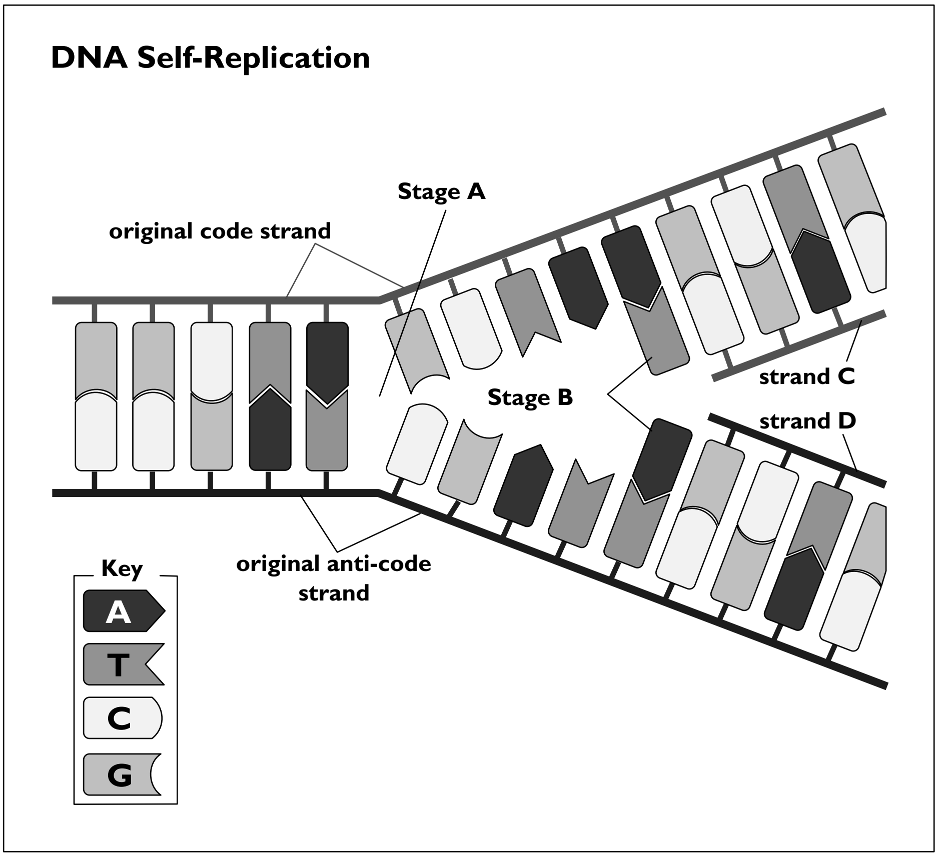
e Why will the reference genome not be any one particular person's?

f What percentage of the reference genome will be common for everyone?

g How do geneticists map where the gene for a particular protein is located?

h When was the sequencing of the base pairs completed?

10 The diagram below shows an outline of the process of self-replication by DNA molecules. Study it carefully, then answer the questions below.



a What is the sequence of bases running along the original code strand (reading from left to right)?

b What is the sequence of bases running along the anti-code strand?

c What is happening to the two strands at stage A? In which direction does this occur?

d What is happening to the two original strands at stage B? In which direction does this occur?

e Identify whether the new strands C and D are code or anti-code.

f What property of the bases does self-replication rely on?

g What is the end result of self-replication?

Unit 5

Applied Genetics

Learning outcomes

On completing this unit you should be able to:

- ☐ Explain the difference between phenotype and genotype
- ☐ Identify heterozygous and homozygous genotypes
- ☐ Explain how dominant and recessive genes operate
- ☐ Use a punnet square to predict the frequency of phenotypes
- ☐ Use a pedigree chart to identify the genotypes of family members

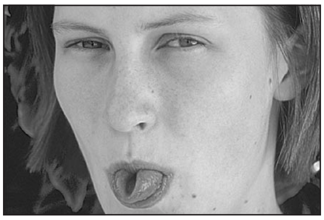


Figure 5.1a This person may have one or two roller genes

Figure 5.1b This person definitely has two non-roller genes

Phenotype and genotype

Gametes have one **gene** for each **trait**. At **fertilisation**, when a sperm fuses with an egg to give a **zygote**, the new **organism** has two genes for each trait – one inherited from each parent.

The appearance of a trait is called the organism's **phenotype**, e.g. if the trait is tongue rolling, there are two phenotypes – rolling and non-rolling.

The genes an organism possesses for a trait are called its **genotype**. Organisms usually have two genes in their genotype for each trait (see Figure 5.1a and 5.1b).

For some genes there are alternative forms, which are called **alleles**. For tongue rolling, there is one allele that codes for the ability to roll one's tongue and another allele that codes for non-rolling.

If the two genes in the genotype are the same allele, then the resulting phenotype is obvious, e.g. a person with two roller alleles can roll and a person with two non-rollers alleles can't. When the two genes are the same, the organism has a **homozygous** genotype and is said to be pure-breeding.

If the two genes are different, then the organism has a **heterozygous** genotype. Usually only one of the alleles will be expressed in the phenotype. If a person has both a roller and a non-roller gene, it turns out that the individual can roll their tongue.

Dominant and recessive genes

The allele that is always expressed is called the **dominant gene**, and the one whose presence may be hidden is called the **recessive gene**.

The dominant form of a gene is written as a capital letter and the recessive as the same letter in lower case. So, if the dominant tongue roller gene is written **R**, then the recessive non-roller gene would be written **r**.

If a person has two roller genes (**RR**), then the individual has a **homozygous dominant** genotype. If the person has two non-roller genes (**rr**), then the individual has a **homozygous recessive** genotype.

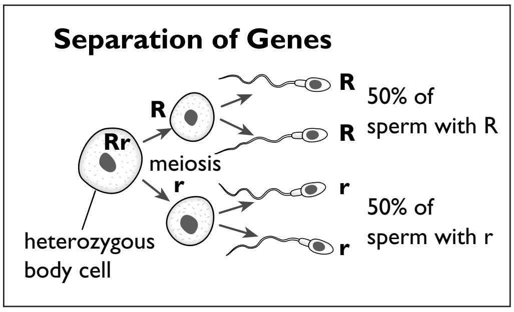


Figure 5.2 Separation of genes

For a recessive gene to be expressed, the organism must possess two of them (e.g. genotype **rr**), but a dominant gene will be expressed whether you have one or two of them (e.g. genotypes **RR** and **Rr**).

A single dominant gene will do or two recessives!

Chance in genetics

In the ovaries and testicles many body cells undergo **meiosis** and produce huge numbers of gametes.

When an organism produces gametes, the two genes it has for each trait are separated in such a way that each gamete gets only one gene. If the organism is homozygous (e.g. a female who is **RR**) then 100% of the gametes will have the same gene (all eggs will be **R**).

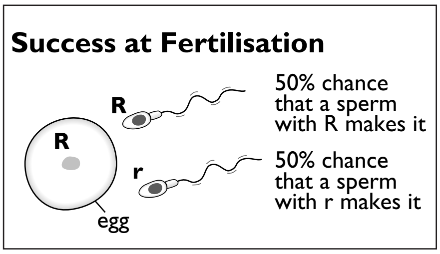


Figure 5.3 Success at fertilisation

But if the organism is heterozygous (e.g. a male who is **Rr**) then 50% of the gametes will land up with one allele (e.g. sperm with **R**) and 50% will have the other allele (sperm with **r**).

In our example, at fertilisation there will be a 50% chance that the successful sperm has the dominant allele **R** and a 50% chance that it has the recessive allele **r**.

Activity 1 Using a punnet square

By using a **punnet square** the possible genotypes of offspring can be identified. You can then work out what the expected phenotypes will be and what the chances of their occurrence are.

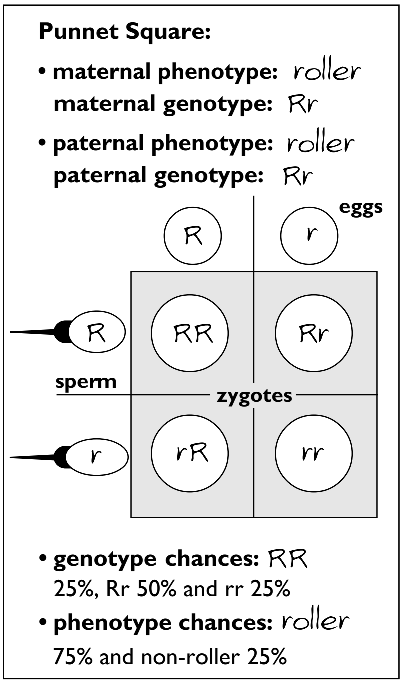
Note that each of the boxes in the punnet square is equally likely to occur, so there is a 25% chance of each zygote happening. Also, genotypes **Rr** and **rR** are the same.

Problem:

If two parents are both heterozygous for the tongue rolling gene, predict their chances of getting the different kinds of offspring.

Steps:

1. Write down the phenotype and genotype of each parent: both father and mother are rollers with an **Rr** genotype.
2. Identify the type of gametes that will be produced by each parent: both parents will produce gametes with **R** and gametes with **r**.
3. To the left of the square write the genotypes of sperm: **R** and **r**. Above the square write down the genotypes of eggs: **R** and **r**.
4. In each box record the genotype of the zygote formed if the sperm on the left met the egg from above: e.g. **r** sperm and **R** egg gives **rR**.



Punnet Square:

- **maternal phenotype:** roller
  maternal genotype: Rr
- **paternal phenotype:** roller
  paternal genotype: Rr

- **genotype chances:** RR 25%, Rr 50% and rr 25%
- **phenotype chances:** roller 75% and non-roller 25%

5 Identify the distinct genotypes and the chances of getting each:
RR = 25%, **Rr (and rR)** = 25% + 25% = 50%, **rr** = 25% chance.

6 Finally decide what the expected ratio of the two phenotypes will be:
- ❑ rollers (**RR** and **Rr** genotypes) = 25% + 50% = 75% chance
- ❑ non-rollers (**rr** genotype only) = 25% chance

Activity 2 Using a pedigree chart

A **pedigree chart** is used to identify the genotypes of parents and their offspring. A circle represents a female and a square a male. A mating is a horizontal line joining male and female. Offspring are placed on branches under parents. Phenotypes are written outside and genotypes inside circles and squares.

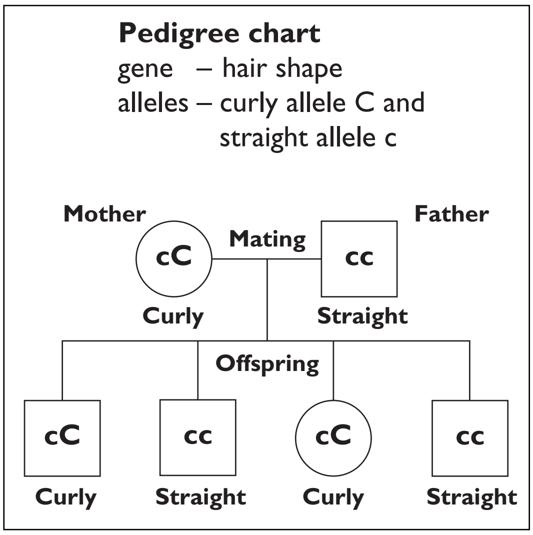
Problem:
The chart gives the natural hair shape of family members. There are two basic phenotypes, curly (includes wavy) and straight hair. The gene for curly hair is dominant over the gene for straight hair.

Steps:

1 Decide on the symbols for the alleles: if the dominant gene for curly hair is written **C**, then the gene for straight hair will be **c**.

2 Two recessive genes are needed for the related phenotype to be expressed: locate all straight-haired individuals and write in their **cc** genotypes.

3 Offspring that have straight hair must have inherited two **c** genes: check their parents have at least one **c** in their genotype, if not add a **c**.



4 Parents in which the recessive gene is expressed will pass on a **c** gene to each of their offspring: make sure each of these offspring have at least one **c** gene in their genotype.

5 The genotypes of some individuals can now be completed so that they will have the phenotype stated: e.g. if an individual has a **c** gene and curly hair then they must have genotype **cC**.

6 For some individuals showing the dominant trait, you still may not know whether they are **CC** or **Cc**: just write in **C?**.

Activity 3

1 Match up definitions with terms.

a gamete	**A** the appearance of a trait
b gene	**B** first cell of a new organism in sexual reproduction
c trait	**C** the two genes an organism possesses are different
d fertilisation	**D** alternative forms of a gene
e zygote	**E** fusion of a sperm with an egg resulting in a zygote
f organism	**F** the organism has two dominant genes in its genotype
g phenotype	**G** cells involved in sexual reproduction (egg and sperm)
h genotype	**H** process of cell division that produces gametes
i allele	**I** a gene that will always be expressed
j homozygous	**J** inherited object that affects the appearance of a trait
k heterozygous	**K** technique used to identify genotypes in a family
l dominant gene	**L** technique used to predict the phenotypes of offspring
m recessive gene	**M** an individual living thing
n homozygous dominant	**N** the two genes an organism possesses are identical
o homozygous recessive	**O** the organism has two recessive genes in its genotype
p meiosis	**P** a gene that is only expressed if the organism has two
q punnet square	**Q** a feature whose appearance is determined by genes
r pedigree chart	**R** the two genes an organism possesses for a trait

2 Explain the differences between the terms below.

a trait and gene

b phenotype and genotype

c homozygous and heterozygous genotypes

d dominant and recessive genes.

3 The photo shows a father and son. The gene for straight hair (c) is recessive to the gene that codes for curly or wavy hair (C).

a What are their phenotypes?

b What genotype will each have?

c Are the father and son homozygous or heterozygous?

d What can you say for sure about the mother's genotype?

e What can you say about the mother's phenotype? (explain)

4 The daughter can roll her tongue but her mother cannot. The gene for tongue rolling (R) is dominant over the gene that codes for non-rolling (r).

a What are their phenotypes?

b What genotypes would each have?

c Which person is homozygous?

d What can you say for sure about the father's genotype and phenotype?

5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** Gametes have two genes per trait and organisms have one.
- **b** Meiosis produces gametes and fertilisation produces a zygote.
- **c** Phenotype describes the appearance of an organism for a trait, while the term genotype describes the genes an organism has for that trait.
- **d** Organisms usually have one gene in their genotype for a trait.
- **e** In a heterozygous genotype the two genes are the same.
- **f** A dominant gene can mask the presence of a recessive gene.
- **g** For a recessive gene to be expressed, an organism requires two of them.
- **h** For a dominant gene to be expressed, an organism needs to be heterozygous or homozygous dominant.
- **i** Ovaries produce eggs and testicles produce sperm.
- **j** With a heterozygous individual, 50% of gametes will have a recessive gene.

6 In rabbits there is a gene that controls whether fur is brown or white. The allele coding for brown fur (B) is dominant over the allele coding for white fur (b).

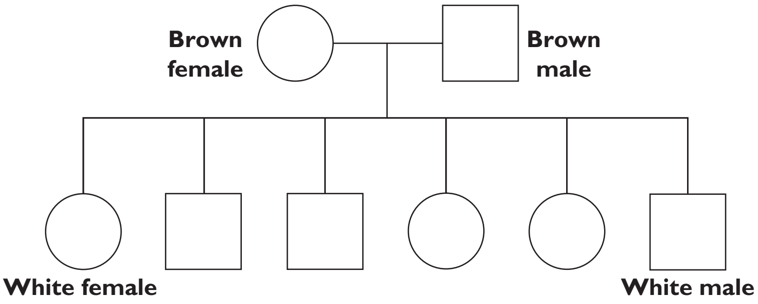
- **a** Would a pure-bred rabbit be heterozygous or homozygous?
- **b** What would the genotype of each of these rabbits be?

Two rabbits were crossed (mated), a pure-bred white female and a pure-bred brown male, and five brown baby rabbits were produced.

- **c** What would the genotypes of each of these rabbits be?

When these brown rabbits reached maturity, a male and female were mated and they produced the white and brown offspring shown in the pedigree chart below.

- **d** Complete the chart to show the genotypes of all rabbits (BB, Bb, bb or B?).



7 In guinea pigs there is a gene that controls whether fur is black or brown. The allele coding for black fur (B) is dominant over the allele coding for brown fur (b).

A breeder wished to produce black guinea pigs for a pet shop chain, but she was unsure whether her stock of black male guinea pigs were all pure breeding for coat colour. So she decided to carry out *test crosses* to uncover any recessive brown genes in her males. Basically this involved crossing each of the black male guinea pigs with a brown female guinea pig and then checking the coat colour of offspring.

- **a** Complete a punnet square to predict the expected offspring if a black male was pure breeding for black coat colour.
- **b** Complete another punnet square to predict the expected offspring if a black male had a recessive brown gene.

The table below shows the actual results from her test crosses.

Male	**Offspring in Litter**
Angus	5 black
Mac	3 black, 3 brown
Pesky	5 black
Rastus	3 black, 2 brown

c Which males are likely to be homozygous dominant? Why?

d Which males are heterozygous? How do you know?

e Which males definitely have a recessive allele for brown hair?

f Which males should the breeder eliminate from her breeding programme?

g In general why are test crosses used by breeders, and what genotype does the test cross organism need to be?

8 Read the passage below, then answer the questions that follow.

Left- or Right-Handed?

Approximately 75% of the human population are strongly right-handed and approximately 90% are predominantly right-handed. Humans are the only species with a consistent bias to one particular side of the body.

Among the remaining 10%, a great deal of variability exists. Some people are strongly left-handed and others are left-handed for some tasks and right-handed for others (ambidextrous).

The preference of individual humans could be due to inherited variation (i.e. genes) or to acquired variation (e.g. training and social pressures in childhood) or a combination of both.

Left-handedness does run in families, and as far fewer people show left-handedness it could be that left-handedness is due to a recessive gene.

But if the situation was a simple case of dominance and recessiveness you would expect that all children of two left-handed parents would be left-handed, but it turns out that about 50% are right-handed and 50% left-handed.

Identical twins have identical genotypes, so if handedness was fully determined by genes, then we would expect that if you knew the handedness of one twin you should be able to correctly predict the handedness of the other. But this does not turn out to be true.

Many geneticists currently accept that right-handedness is mostly determined by genes, but left-handedness is more variable.

The geneticist Marian Annett proposed that a single gene is involved that has two alleles.

The dominant allele R+ has a strong tendency to cause right-handedness whether you inherit one or two.

The recessive form of the gene R- does not cause left-handedness if you have two of them, rather it does not produce a bias towards either form of handedness. So people who have two recessive genes are free to develop either left- or right-handedness or they may become ambidextrous.

a In what way is the human species unique?

b What does the term 'ambidextrous' mean?

c What evidence supports the idea that handedness is influenced by genes?

d What two pieces of evidence suggest that handedness is not determined by simple dominance and recessiveness?

e What two genotypes are right-handed people likely to have?

f If you have an R+ gene, what are you likely to be?

g If you have two R- genes, what are you likely to be?

9 With the gene coding for hair shape there are two alleles. Dominant gene C codes for curly (including wavy) hair and c codes for straight hair.

There are two phenotypes (curly and straight) and three possible genotypes (CC, Cc and cc).

In this activity you will investigate what offspring can be expected with each combination of parents. It turns out that there are six distinct combinations of parental genotypes possible. These are listed down the left side of the table.

Complete the table by working out the chances of getting the different genotypes and phenotypes amongst the offspring. A few are obvious, but with others use a punnet square.

Parents	Offspring Genotypes	Offspring Phenotypes
CC x CC	CC =__% Cc =__% cc =__%	curly =__% straight =__%
CC x cc	CC =__% Cc =__% cc =__%	curly =__% straight =__%
CC x Cc	CC =__% Cc =__% cc =__%	curly =__% straight =__%
Cc x Cc	CC =__% Cc =__% cc =__%	curly =__% straight =__%
Cc x cc	CC =__% Cc =__% cc =__%	curly =__% straight =__%
cc x cc	CC =__% Cc =__% cc =__%	curly =__% straight =__%

a Which combination involves two homozygous dominant parents?

b Which combination involves two homozygous recessive parents?

c Which combinations of parents will produce only one type of phenotype amongst their offspring?

d Which combination of parents will give some offspring which are different from both parents?

e Explain why it is possible for two curly-haired parents to produce a straight-haired child and why it is impossible for two straight-haired parents to produce any curly-haired children.

Unit 6

Bacteria, Fungi And Viruses

Learning outcomes

On completing this unit you should be able to:

- ☐ Define micro-organisms
- ☐ Draw and label a bacterium, a virus and a fungi
- ☐ Describe feeding, excretion and reproduction in bacteria
- ☐ Illustrate how a virus replicates
- ☐ Describe nutrition and reproduction in fungi

Micro-organisms

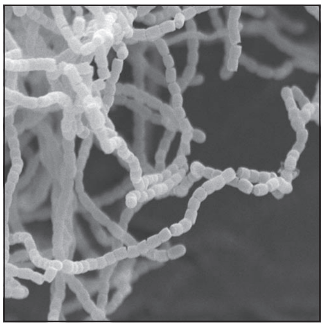


Figure 6.1 Microscopic view of a bacterial colony

Micro-organisms (or microbes) are very small organisms, which are usually only visible with the aid of a microscope. Sometimes a colony of micro-organisms can be seen with the naked eye.

Micro-organisms that are single cells are unicellular. Those made of many cells are multicellular.

Even though micro-organisms are not easily seen, the results of their activity can be. Harmful micro-organisms spoil food, damage crops and cause diseases.

All organisms are made of cells and need to carry out the following life functions to survive: move, feed, circulate materials, respire, excrete, sense changes, reproduce and grow. Micro-organisms must carry out all of these activities too.

The three main groups of micro-organisms are the bacteria, viruses and fungi.

Bacteria – structure and roles

Bacteria are very small organisms and there are thousands of different types. Some are unicellular and others consist of connected cells. Helpful bacteria produce medical drugs, foods (e.g. yoghurt), decompose dead organisms, and help digest food in your gut. Harmful bacteria rot food and cause diseases such as typhoid, syphilis and tetanus.

Bacteria have no **cell nucleus**. Their **genes** are found along a **chromosome**. The chromosome controls the activities of bacteria. The bulk of the cell is the **cytoplasm** where the chemical reactions of life occur. It is enclosed by the **cell membrane**, which controls the entry and exit of chemicals. Outside the membrane is a stiff cell wall, which provides support. Some bacteria can swim using a propeller-like flagellum; others glide about.

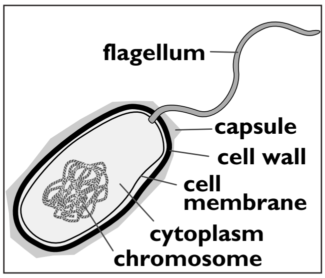


Figure 6.2 Bacteria

Most bacteria are consumers and cannot make their own food. If the bacteria live in and feed off larger organisms, they are parasites. If they cause disease, they are **pathogens**. If the bacteria grow on dead material (e.g. compost), they are decomposers.

Bacteria – feeding, excretion and reproduction

Bacteria feed by releasing **digestive enzymes** on to dead or living matter. The large food molecules are broken down into smaller ones that are absorbed into the bacteria. This is known as **extra-cellular digestion.**

Energy is usually released from food molecules in a process called **aerobic respiration**, which requires oxygen. Bacteria can release energy from food without requiring oxygen (**anaerobic respiration**). Wastes produced by bacteria are excreted by diffusing out into their environment.

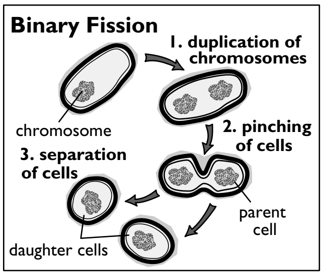


Figure 6.3 Binary fission

Bacteria multiply very rapidly by repeatedly dividing in two. First the chromosome is duplicated, then the cell pinches in half and two separate 'daughter' cells are formed, each with a chromosome. This form of asexual reproduction is called **binary fission**. The offspring all have identical genes.

When conditions are inhospitable, some bacteria form resistant **spores** that can survive for years. When the spores land on dead or living tissue, they germinate and multiply.

Viruses – alive?

Viruses are extremely small objects, much smaller than bacteria. Viruses do not feed or move; they can only reproduce by taking over living cells. Viruses are not cells, nor are they alive.

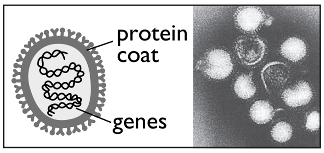


Figure 6.4 Common cold virus

A virus consists of a string of genes coiled up inside a protein coat. The coat can form different shapes. There are thousands of different types of viruses.

Viruses are very efficient at reproduction. When a virus lands on the surface of a cell, it inserts its genes into the host cell. The virus takes over the cell and makes it assemble thousands of copies of the virus in a process called **replication**. The cell then bursts, releasing the new viruses which spread to other cells or organisms.

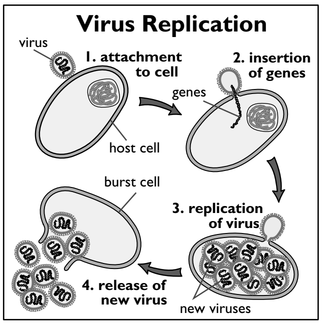


Figure 6.5 Virus replication

The genes of viruses readily change or mutate, which is why new strains of viruses regularly emerge (e.g. 'bird flu' virus, which appeared in Hong Kong in 1997).

Viruses are pathogens, as the host cells are always damaged by the virus. Viral diseases include colds, flu, hepatitis B and Aids.

Fungi – structure and roles

Fungi are a large group of organisms, which include unicellular yeasts as well as multicellular moulds, mushrooms and toadstools.

Fungi, like plants, are immobile, but unlike plants they cannot make food. So they must live off other organisms. Most fungi are **saprophytes**, living on dead organisms or products of organisms (e.g. bread and cheese). Other fungi are parasites on living organisms, absorbing food from them. Fungi that are human parasites cause thrush and athlete's foot.

Although some fungi spoil food and cause disease, other fungi are helpful. They break down dead organisms and are used to produce bread, wine and cheese.

Multicellular fungi are made up of a mass of very fine threads called **hyphae**, which invade the tissue of the host organism or dead matter. Fungi feed like bacteria by releasing digestive enzymes onto food (extra-cellular digestion).

Fungi are spread by microscopic cells called spores that have tough walls. Special spore capsules or cases called **sporangia** develop and produce the spores. Millions of spores are released to float in the air. When the spores settle on dead or living tissue they germinate, sending out hyphae that rapidly branch and invade the new host.

When spores are produced by a single 'parent', this is a form of asexual reproduction giving genetically identical offspring. Fungi can also reproduce sexually, which produces variation amongst the offspring.

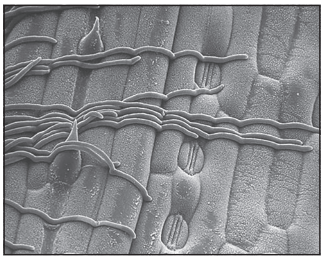


Figure 6.6 Hyphae invading plant cells

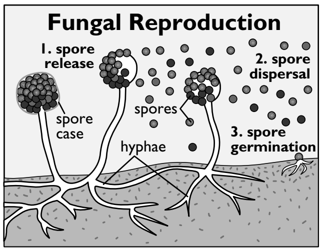


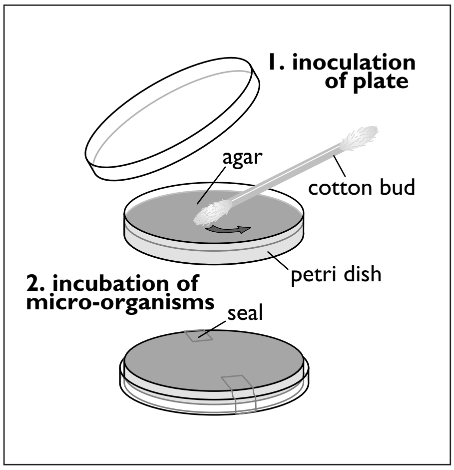
Figure 6.7 Fungal reproduction

Activity 1 Culturing micro-organisms

Micro-organisms can be grown on a special medium called agar, which contains all the nutrients required for growth. The heated, sterile agar is poured into petri dishes where it sets into a jelly.

Growing bacteria and fungi:

1. Lightly wipe a cotton bud or ball over the surface of the object that you are investigating.
2. Lift the lid of the petri dish and gently brush the bud or ball over the surface of the agar. Quickly replace the lid. This is called **inoculation**.
3. Place the dish upside down to prevent water condensing on the agar and seal it with tape.
4. Incubate the micro-organisms in a warm place for several days.
   DO NOT REOPEN THE DISH.

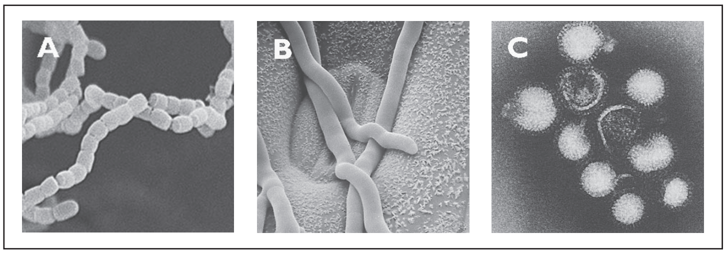


Activity 2

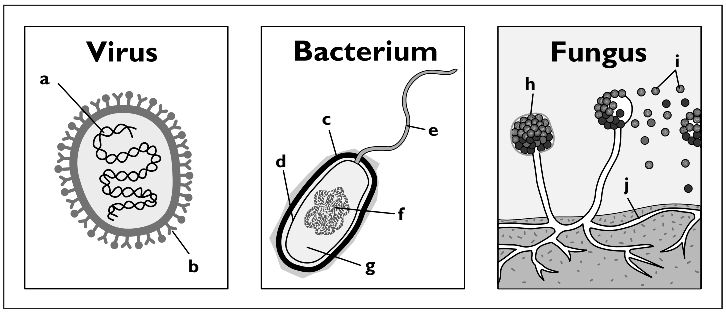
1 Match up terms with definitions.

a micro-organism	**A** group of immobile organisms that feed on others
b bacteria	**B** control centre of a cell containing chromosomes
c cell nucleus	**C** a tough-walled resistant reproductive cell for dispersal
d gene	**D** chemicals that break down large food molecules
e chromosome	**E** production of multiple copies of a virus
f cytoplasm	**F** bulk of the cell where reactions of life occur
g cell membrane	**G** organism that feeds on dead organisms
h pathogen	**H** inherited instruction determining a feature
i digestive enzymes	**I** fine threads of a fungus that invade the host
j binary fission	**J** encloses cell and controls entry and exit of chemicals
k spore	**K** micro-organisms that do not have a cell nucleus
l viruses	**L** non-living objects that use cells to make new copies
m replication	**M** collection of genes connected in a long chain
n fungi	**N** to introduce micro-organisms on to agar
o saprophyte	**O** a disease-causing organism
p hyphae	**P** splitting into two organisms through cell division
q inoculate	**Q** very small organism visible under the microscope

2 Identify the following micro-organisms.



3 Copy and label the three micro-organisms shown below. Choose from the terms in the box.



• cell wall • chromosome • genes • spores • cell membrane •
• cytoplasm • protein coat • hyphae • flagellum • spore case •

k Which of the three objects are considered to be alive?

l What activity do all three objects carry out?

m Why are these objects called micro-organisms?

4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** You always need a microscope to see a micro-organism.
- **b** Unicellular organisms consist of one cell only, but multicellular organisms are made of many cells.
- **c** Bacteria, fungi and viruses are all living organisms.
- **d** Bacteria can be both helpful and harmful to humans.
- **e** The genes of a bacteria are found on a single chromosome floating in the cell cytoplasm.
- **f** Organisms that live on dead bodies are called pathogens.
- **g** Bacteria and fungi carry out digestion of food outside of their bodies.
- **h** Spores are usually a form of sexual reproduction.
- **i** Viruses take over living cells and make the cells produce new viruses.
- **j** Both bacteria and fungi play important roles as decomposers.

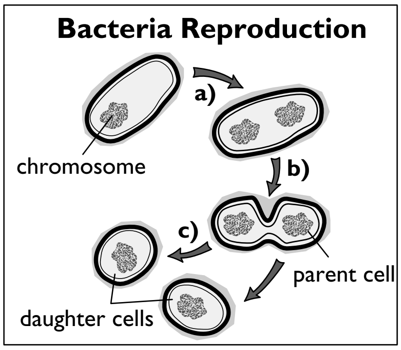
5 Copy and complete the following paragraphs using the words in the box opposite.

- **a** Most bacteria are __________ as they are unable to make their own food. Bacteria digest their food by releasing digestive ________. Those that live on and feed off larger organisms are called __________. Many bacteria cause disease and are __________.
- **b** Fungi are ________ like plants, but are unable to make their own ____. Fungi that feed on dead matter are ____________, others are parasites. Fungi ______ their food externally.
- **c** Viruses do not feed; they can only __________ using living _____ that they invade. All viruses are __________ as they damage hosts.

cells
consumers
digest
enzymes
food
immobile
parasites
pathogens
reproduce
saprophytes

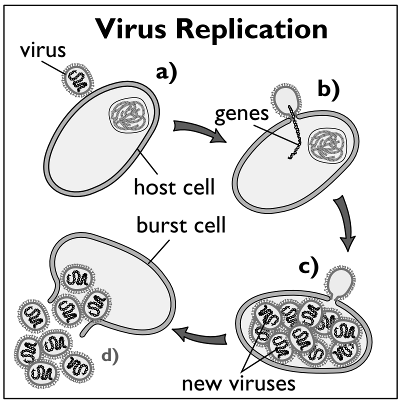
6 Describe the events **a** to **c** in the diagram.

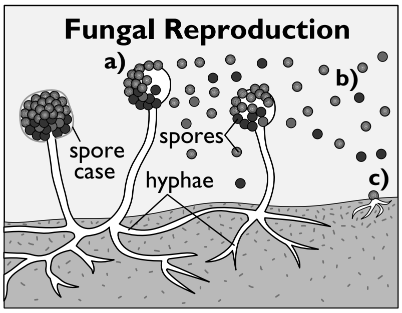
- **d** What is this form of reproduction called?
- **e** Is it sexual or asexual?
- **f** What is the advantage?
- **g** What is the limitation?



7 Describe events **a** to **d** in the diagram.

- **e** What is this form of reproduction called?
- **f** Can viruses reproduce independently?
- **g** How do viruses use their host cells?
- **h** How do new forms of viruses arise?
- **i** Why are viruses always pathogens?





8 Describe the events shown in **a–c**.

d What is special about spores?

e How are spores spread?

f What happens to the spores?

g Is reproduction sexual or asexual?

9 Write a short paragraph on each of the following topics:

a Fungi – Neither Plants nor Animals

b Viruses – Living or Non-Living?

c Bacteria Lifestyles – Parasites, Pathogens or Saprophytes.

10 Describe the differences between the terms:

a unicellular and multicellular

b internal and external digestion

c inoculation and incubation.

11 Read the passage below, then answer the questions that follow.

'Bird flu' virus threat

Scientists are concerned that the 'bird flu' virus, which first appeared in Hong Kong in 1997, could result in an epidemic that would rapidly spread across the world. Hundreds of millions of people could be infected within months because these viruses are easily passed from person to person through the air and because so many people travel between countries.

Flu viruses cause the illness influenza. Most flu virus strains produce a relatively harmless infection, but some strains have devastating effects on young and old people as well as those in poor health.

In 1918 the Spanish influenza virus killed somewhere between 20 and 40 million people. In 1957 the Asian flu killed over a million people.

The 'bird flu' virus is unusual in that it appears to have crossed the species barrier. Somehow the virus has been transferred from its original bird hosts to human beings who have handled them. Humans usually experience symptoms of sore throats, fever and headaches.

Initially about a quarter of the 17 people identified as having the virus died. This indicated it was a very virulent strain.

So far there has been no evidence of person-to-person transmission of the virus, which would be serious if it began to occur. All patients appear to have caught the virus directly from birds or bird products.

Hong Kong slaughtered over a million chickens in an attempt to rid itself of the deadly virus.

Scientists have isolated the virus and are attempting to modify it to produce a vaccine. The vaccine would contain a weakened form of the virus, which would provide resistance to infection.

a What is meant by the term 'epidemic'?

b Why is it that flu viruses are usually able to spread so rapidly around the globe?

c What are the typical symptoms of the flu?

d Why is the 'bird flu' virus unusual?

e How could the virus have been transferred from birds to humans?

f What would the virus do once it had entered a human cell?

g Why is the 'bird flu' virus considered to be a virulent strain?

h What was the 'good news' about the 'bird flu' virus?

i How does a vaccine help give people immunity to a virus?

12 Bacteria found living in the human gut can divide in two every 20 minutes. This can result in a huge population explosion. Complete the table opposite showing the number of bacteria over an 8-hour period, when nothing inhibited their growth.

a What is this form of reproduction called?

b What happens to the total number of bacteria every 20 minutes?

c What will all the bacteria formed by the end of the eight hours have in common?

d If you graphed the population numbers against time, what would the line be like?

e Could the number of bacteria continue to increase indefinitely?

f What factors would eventually limit the size of the bacterial population?

g What would happen to the shape of the graph as these factors came into operation?

h How would these bacteria obtain their food?

Time	Bacteria
Start	1
20min	2
40min	4
1hr	8
1hr 20min	
1hr 40min	
2hr	
2hr 20min	
2hr 40min	
3hr	
3hr 20min	
3hr 40min	
4hr	
4hr 20min	
4hr 40min	
5hr	
5hr 20min	
5hr 40min	
6hr	
6hr 20min	
6hr 40min	
7hr	
7hr 20min	
7hr 40min	
8hr	

Unit 7

Helpful Or Harmful?

Learning outcomes

On completing this unit you should be able to:

- ☐ Describe the action of helpful micro-organisms
- ☐ Describe the body's defences against harmful micro-organisms
- ☐ Explain how immunity against pathogens occurs
- ☐ Explain how antibiotic resistance develops in bacteria
- ☐ Design a fair test of the effectiveness of antiseptics

Naturally helpful

Many bacteria and fungi are decomposers breaking down dead tissue (e.g. in compost heaps). These micro-organisms release chemicals (nutrients) that plants can absorb. They form an important part of the carbon and nitrogen nutrient cycles.

Carbon is released from dead matter by decomposers into the atmosphere as carbon dioxide gas, which is then absorbed by plants as they manufacture food. Nitrogen is released into the soil in the form of nitrates, which plants absorb through their roots.

Nitrogen-fixing bacteria found in the roots of plants like clover convert nitrogen gas from the air into nitrates, which increases crop productivity.

Cellulose-digesting bacteria in the gut of herbivores help break down the thick cell walls of plant tissue giving the animal extra nutrition.

Biotechnology

Humans have found many ways of using micro-organisms to produce foodstuffs, better crops, medical drugs and consumer products. This use of micro-organisms for human ends is called **biotechnology**.

Yoghurt bacteria convert lactose sugar in milk into lactic acid, which solidifies the milk into yoghurt. Other bacteria are involved in curdling milk for cheese making. Pharmaceutical companies use **genetically engineered** bacteria to produce chemicals for medical drugs. Special bacteria produce insulin, which is used by diabetics to control their blood sugar levels.

Yeasts are an important group of fungi that convert sugar into carbon dioxide and alcohol by **fermentation** (a form of anaerobic respiration). These micro-organisms are used to make bread rise and to ferment beer and wine. Other fungi produce chemicals called antibiotics that are used to fight bacterial infections.

Some viruses are used to control pest organisms, e.g. calicivirus (RCD) has been introduced into New Zealand to control rabbit populations. This use of micro-organisms is called **biological control**.

Harmful micro-organisms

Micro-organisms that cause disease are called **pathogens**. Other micro-organisms cause harm by damaging crops, foodstuffs and fabrics.

As viruses are all pathogens, they cause many human diseases from relatively harmless colds and flus through to serious diseases such as polio, hepatitis B and Aids.

Some bacterial species cause food to rot. Colonies of bacteria can be seen as shiny spots on meat that has gone off. Listeria bacteria, which are found in shellfish at times, can cause food poisoning and damage foetuses.

Different fungal species can cause dry rot in timber, make food rot (e.g. bread mould and potato blight) and make fabrics go mouldy. Some species of fungi infect humans (e.g. thrush and athlete's foot).

Catching and fighting off diseases

Pathogens cause many human diseases, but not all diseases are caused by micro-organisms (e.g. hereditary diseases, cancers and heart disease).

Disease-Spreading Agents

☐ air – e.g. cold and flu viruses from sneezing

☐ skin contact – e.g. thrush from touch

☐ water – e.g. giardia in lake water

☐ food – e.g. listeria bacteria in shellfish

☐ body fluids – e.g. Aids virus in blood

When a pathogen grows in your body, an **infection** occurs. The pathogen may damage tissue or produce **toxins** that poison cells.

Your body has some sophisticated defences against these pathogens.

☐ **Defence 1:** Barrier and Chemical Warfare

Your watertight skin is a barrier to keep out pathogens. If they enter body openings, then the enzyme lysozyme in tears, saliva, nose mucus and urine kills microbes. Stomach acid kills most of the bacteria on food.

☐ **Defence 2:** Phagocytes – Generalists

If pathogens make it through into your body tissue, then patrolling white blood cells called **phagocytes** attack and engulf the micro-organisms.

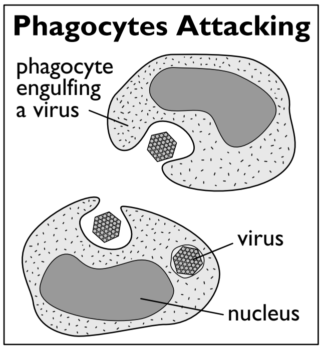


Figure 7.1 Phagocytes attacking

❑ **Defence 3:** Lymphocytes – Specialists

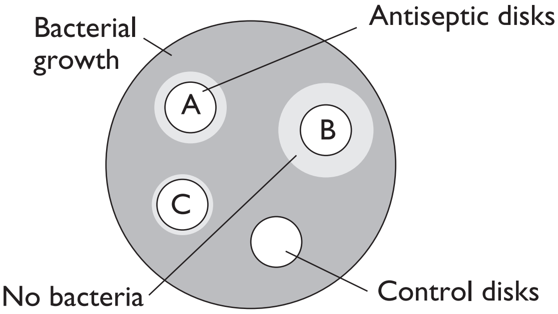
On the outer surface of each type of pathogen are unique marker chemicals called **antigens** that escape into the blood. White blood cells **lymphocytes** absorb the antigens and release a chemical called an **antibody** into the blood. The **antibody** recognises the pathogens that made the antigen and destroys them. As different pathogens have different antigens, blood has many different antibodies floating in it.

Activity 1 Fair testing

Antiseptics applied to cuts prevent infections. Imagine you have been asked to compare the effectiveness of different antiseptics at killing bacteria. How do you conduct a fair test? The key is to ensure that all conditions are kept identical.

Setting up a fair test:

1. Firstly obtain identical sterile petri dishes with nutrient agar.
2. Next make up a standard solution of each antiseptic (e.g. 5 ml per 100 ml of water).
3. Cut identical small disks of filter paper and label them. Dip each in a different antiseptic. Dip one disk in water as a control.
4. Obtain bacteria from the same source by wiping a cotton swab over an existing colony. Lightly wipe the swab over the agar in a petri dish. Drop the antiseptic disks on to the agar.
5. Seal the dish. Place in an incubator for three days.
6. Clear areas in the agar indicate bacteria are absent. Observe the size of the clear area around each disk and decide which antiseptic is the most effective.



Immunity to disease

When you are first infected by a particular pathogen, the organisms multiply rapidly causing the symptoms. As antibody levels slowly build up, the pathogens are killed.

You then have natural **immunity** to further infection from that pathogen, because you already have large numbers of the right antibody in your blood.

You can gain artificial immunity to a disease by being injected with weakened or dead pathogens in a **vaccination**. These pathogens stimulate lymphocytes to produce the right antibody in preparation for a real infection.

Vaccination works with viruses and bacteria. Some viruses, like cold and flu viruses, mutate rapidly and it is difficult to develop an effective vaccine.

Antibiotic resistance

Antibiotics are chemicals produced by fungi that are very effective at destroying bacteria. These medical drugs, which are taken internally as pills or in solution, kill invading pathogens without damaging human cells.

Unfortunately, some bacteria develop **resistance** to a particular antibiotic. Bacteria belonging to one species are not all the same; their genes can change by mutation. Some bacteria acquire resistance to a particular antibiotic and are not killed by it. They multiply, passing their resistant genes on to their offspring.

As bacteria that are vulnerable to the antibiotic are killed off, the population gradually changes to a resistant strain. New antibiotics then have to be developed to fight these pathogens.

Activity 2

1 Match up terms with definitions.

a biotechnology	**A** isolation of a person with a serious infectious disease
b genetic engineering	**B** using predators, parasites or pathogens to control pests
c fermentation	**C** growth of harmful micro-organisms in or on your body
d biological control	**D** making use of micro-organisms for human ends
e pathogen	**E** chemical that recognises and helps destroy a pathogen
f infection	**F** marker chemical on a pathogen
g toxin	**G** ability to prevent an infection occurring
h phagocyte	**H** modification of the genes of organisms by humans
i antigen	**I** white blood cell which produces antibodies
j lymphocyte	**J** a disease-causing micro-organism
k antibody	**K** conversion of sugar into alcohol and carbon dioxide by yeast
l antiseptic	**L** when bacteria are no longer affected by an antibiotic
m immunity	**M** chemical produced by a pathogen which may poison cells
n vaccination	**N** chemical produced by fungi that is used to kill bacteria
o antibiotic	**O** white blood cell that engulfs pathogens
p antibiotic resistance	**P** chemical applied to a wound to prevent infection
q quarantine	**Q** injection with dead or weakened microbes to give immunity

2 Copy and complete the following table by listing harmful and helpful effects of micro-organisms.

Micro-organism	Harmful Effect	Helpful Effect
viruses	☐	☐
bacteria	☐	☐
fungi	☐	☐

3 Identify the micro-organism involved.

4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

a Decomposers are micro-organisms that are able to release nutrients from dead matter.

b Herbivores need the assistance of fungi that live in their gut to break down the tough cell walls of plants.

c Biotechnology can involve the use of micro-organisms for the good of humans.

d Antibiotics are used to fight both bacterial and viral infections.

e Viruses are all pathogens, but they can be useful when they are used for the biological control of pests.

f All diseases are caused by pathogens.

g A pathogen can cause harm by destroying living tissue or by poisoning cells with the toxins it produces.

h A pathogen produces antigens, which are absorbed by lymphocytes, which then produce antibodies to attack that pathogen.

i Immunity occurs through antibodies.

5 Explain the difference between:

a biotechnology and biological control

b antigen and antibody

c disinfectant and antiseptic

d immunity and vaccination.

antibodies
antibody
antigens
artificial
bacteria
blood
cells
engulf
fungi
immunity
pathogen
pathogens
resistance
vaccinated

6 Copy and complete the following paragraphs using the words in the box.

a White blood _____ are involved in fighting ________. Phagocytes ______ any pathogens they encounter. Lymphocytes produce __________, which attack and help destroy particular types of pathogens. The antibodies recognise ________ on the surface of the pathogen.

b After your first infection by a particular ________, you gain natural ________ to further attacks due to the presence of ________ in your blood. You can gain _________ immunity to a particular pathogen by being __________ with dead or weakened strains of the pathogen. This increases the level of the appropriate antibody in the ______.

c Antibiotics are produced by ______ and are taken internally by humans to destroy ________. Some bacteria have developed _________ to particular antibiotics. A few of the bacteria are genetically different and are not killed by the antibiotic. They increase in number and eventually produce a resistant strain.

7 In an investigation into the effectiveness of three disinfectants (A, B and C), students inoculated a sterile agar plate with bacteria from an established colony by wiping the surfaces with a cotton bud.

They dipped a small labelled disk into the first disinfectant and placed it on the agar. They repeated this step for the other two disinfectants. The plate was sealed and incubated for three days. The photo opposite shows the results.

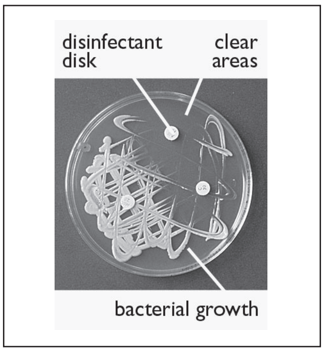


Figure 7.2 Investigation into the effectiveness of bacteria

a What is a disinfectant used for?

b What are the students actually testing?

c What does the word ‘sterile’ mean? Why was it important the plate was sterile to begin with?

d Why did they use bacteria from an established colony?

e What is the difference between inoculation and incubation?

f Why is it important that the filter paper disks were the same size?

g What do the filter paper disks do when dipped in disinfectant?

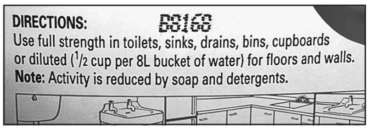
h What do the squiggly lines in the photo indicate? What do the clear areas around some of the disks indicate?

i Which disinfectant appears to be most effective at killing bacteria? How do you know this?

j The teacher commented that this was not a completely fair test. Suggest why it was not a fair test and how the students could change their method to make it fairer. (Hint – read label.)

k The teacher also suggested that they should have included a control disk to check that filter paper does not inhibit the growth of bacteria. What should they do to the control disk to check this?

l Suggest a limitation of this particular test of the effectiveness of disinfectants in killing bacteria in general.



DIRECTIONS: B8168

Use full strength in toilets, sinks, drains, bins, cupboards or diluted ($^1/_2$ cup per 8L bucket of water) for floors and walls.

Note: Activity is reduced by soap and detergents.

Figure 7.3 Label

8 Read the passage below, then answer the questions.

HIV and Aids

The disease Aids (acquired immune deficiency syndrome) is caused by a viral pathogen. The virus is called HIV (human immunodeficiency virus).

The virus first appeared in Africa in the 1980s and it is believed to have originated in a monkey species.

The virus is transmitted from person to person in body fluids (e.g. blood and semen). It can be transferred through sexual activity, blood transfusions and by sharing needles. It is not caught by touching or coughing.

Once the virus enters the body, it invades lymphocytes which fight disease.

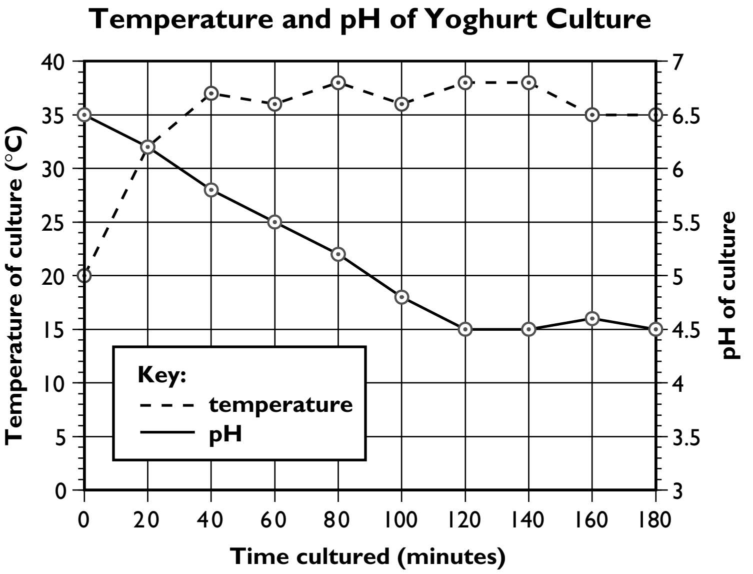
The virus remains dormant in the lymphocytes for up to ten years. When it becomes active the virus takes over the lymphocyte cells and makes them produce many more copies of the virus, which escape to invade other lymphocytes.

The body’s immune system now ceases to function and the person is vulnerable to many opportunistic infections. These include diseases such as thrush, diarrhoea, tuberculosis, pneumonia and some cancers. When these symptoms occur, the person then has Aids. Often there are times of recovery followed by relapse. Eventually the person’s health deteriorates and an infection proves fatal.

Researchers are developing drugs that may prevent the onset of Aids. They are also investigating vaccines, but as the HIV virus mutates rapidly this is a difficult task.

a What do the acronyms HIV and Aids stand for?
b What type of pathogen causes Aids?
c This pathogen has crossed the 'species barrier'. What does this mean?
d Suggest three ways in which the spread of the disease could be reduced.
e What does it mean when a person is tested and found to be HIV positive?
f Why is there usually a long delay between infection with HIV and the development of Aids?
g What are 'opportunistic infections'?
h Why is it difficult to develop an effective vaccine?

9 To culture yoghurt, milk was heated until it nearly boiled; yoghurt-making bacteria were added when the milk had cooled to 20°C. The liquid was placed in a water bath set to 35°C. The temperature and pH of the mixture was monitored over three hours. The results are plotted on the double axis graph below.



a What ingredients are needed to make yoghurt?
b Why was the milk heated till it nearly boiled?
c What was the milk inoculated with?
d What was the purpose of putting the culture in a water bath?
e Describe the trend shown by the temperature graph line.
f Was the water bath thermostat accurately calibrated?
g Why would the water bath thermostat have been set to 35°C?
h Suggest a reason for the temperature fluctuations of the culture.
i The student used a pH meter to find the pH of the culture. What does pH indicate?
j After 100 minutes, what was the temperature and pH of the culture?
k Describe the trend shown by the pH graph line.
l Describe in words what happens to the acidity of the culture during the experiment.
m What would have caused this change in pH?
n After 120 minutes the culture was no longer runny; why was this?

Unit 8

Transport In Plants

Learning outcomes

On completing this unit you should be able to:

- ☐ Conduct an investigation into transport in plants
- ☐ Describe how sugar is transported in plants
- ☐ Describe how water is transported in plants
- ☐ Explain the links between the transport of sugars and water, and growth in plants

Transport in plants

All parts of plants need both water and sugars. Water only enters through the roots, and the leaves are the only source of sugar. Therefore, plants need transport systems to move these substances around.

Plants have a **transport system** that is in some ways similar to an animal's blood circulatory system. However, it is rather different in several important ways. For example, there is no pump like the heart, no circulating cells like blood cells and liquids do not continuously move round and round.

The substances that are transported – mineral salts (ions) from the soil, and the products of photosynthesis (sugars) from the leaves – are dissolved in **water** (as an 'aqueous solution'). The transport system basically consists of two types of conducting tissue, each of which is made from **cells** that have been modified or changed for their special purpose. Some cells die as a result of this modification, and they may also lose some of their internal components.

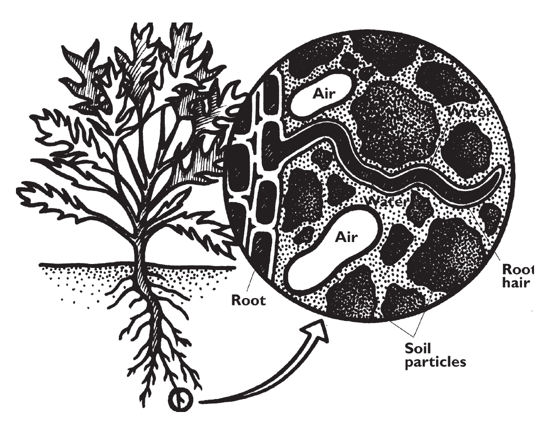


Figure 8.1 Root hairs absorb water and nutrients from the soil

Transport of water and mineral salts

Water and mineral salts enter a plant through special cells called **root hair** cells. The water is taken up by a special form of diffusion called **osmosis** and passes into the root hair, across the cortex to special water conducting tissue called xylem.

Xylem are long tube-like cells that carry water and mineral salts in an upwards direction from the root, through the stem to the leaves. Xylem vessels are dead. The end walls have disintegrated to leave hollow tubes. The side walls have become strengthened with rings or spirals of **lignin**. This helps support the plant and forms the wood in trees.

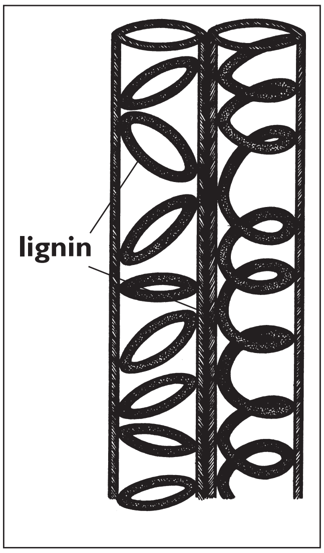


Figure 8.2 Xylem

When water reaches the leaf, it passes into the mesophyll cells. These cells contain the green pigment chlorophyll in small organelles called chloroplasts. It is here that the important food making process called photosynthesis takes place. The chlorophyll absorbs sunlight and stores its energy in the form of chemical potential energy.

Some of the mineral salts pass into the plant with the water during osmosis, but other salts are pumped in by the plant's root cells. This process is called active transport because it uses some of the plant's energy to carry it out.

Inside the leaf

As well as water, the leaf also needs the gas carbon dioxide, which is absorbed by the mesophyll cells from the surrounding air. The carbon dioxide enters through small openings called **stomata**, which are usually on the underside of the leaf. Needle-like leaves have less surface area and so fewer stomata.

Excess water also passes out of these pores in the leaf surface. The evaporation of water through these pores is known as **transpiration**. This process reduces the internal pressure in the leaf and causes a force that pulls the water and minerals up through the xylem from the roots.

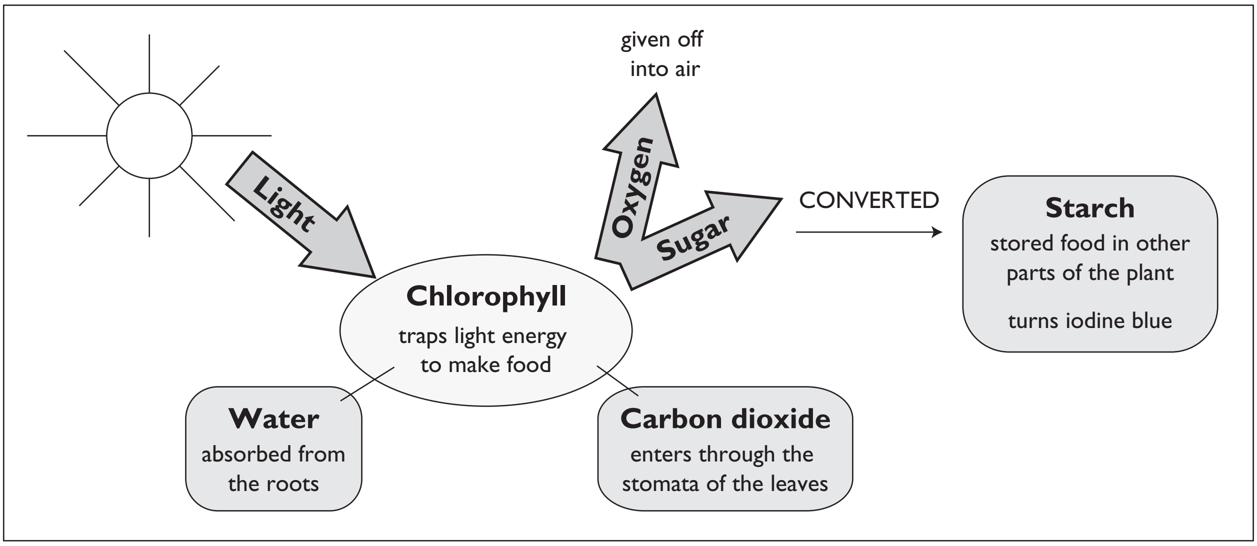


Figure 8.3 Photosynthesis

When the rate of water loss by transpiration is greater than the rate of water uptake by the roots, the leaves begin to droop and wilt.

The leaf carries out the process of photosynthesis. This is a chemical reaction in which carbon dioxide (from the air) and water (from the roots) are combined using the energy from the sun. This reaction produces sugar (converted to starch and used by the plant for growth and for other life processes) and oxygen as a waste product (which is essential for most animal life on earth).

Factors affecting transpiration

More transpiration takes place during the day than at night. This is because the stomata are open during the day and close at night.

The stomata may also close in very dry conditions. This is because water lost in transpiration is not being replaced by water from the soil. The stomata close to reduce transpiration.

If the plant does not get enough water, it will begin to wilt. Its cells have lost so much water they are no longer **turgid** or full of water. Turgid cells are firm and give the plant support.

If the cells lose water, they become **flaccid**, then the plant becomes soft. The stem is no longer upright and the leaves droop.

Other factors that increase transpiration are windy conditions (carries water away from the leaf quicker, low humidity (the air can hold more water), increased air temperature (the air can hold more water) and light (causes the stomata to open).

Transport of sugar

Sugars are produced in the leaf. They must be transported upwards or downwards to other parts of the plant. A small amount of sugar is used by all the plant cells in the process of respiration to provide energy for the cells' activities.

Some sugar is used to build new plant parts such as stems, roots and leaves and fruit. The rest of the sugar is converted to starch and stored. Talo stores its sugar as starch under the ground.

The sugars are carried away from the leaves in phloem cells. Unlike xylem cells, phloem cells are alive. Companion cells provide the energy for the tube cells. The end walls of the tube cells have pores through which food is transported from cell to cell in the form of dissolved sugars.

The plant transports the products of photosynthesis in the form of sugar, which is soluble in water. It stores the products as starch, which is insoluble.

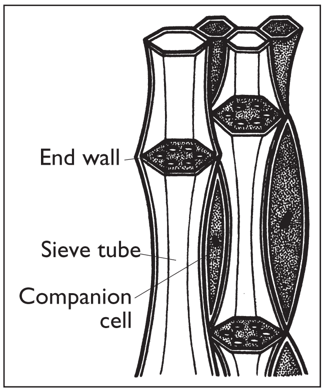


Figure 8.4 Transport of sugar

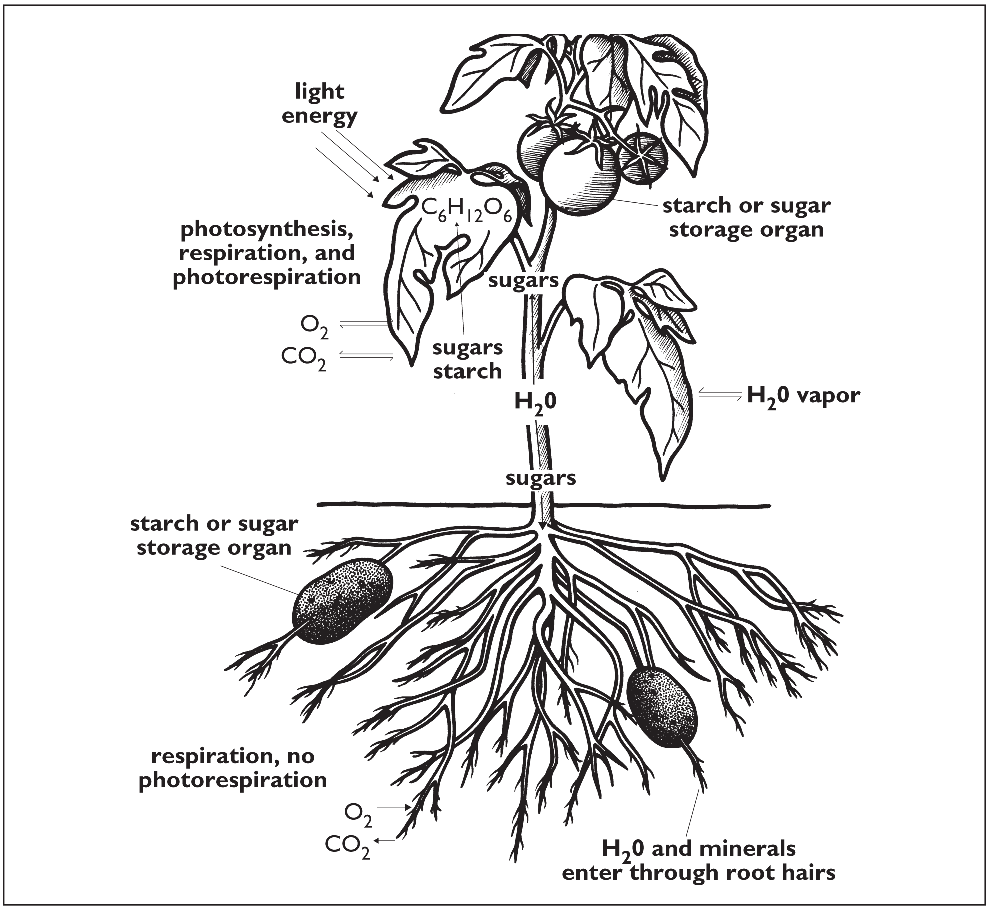


Figure 8.5 Photosynthesis, respiration, leaf water exchange and translocation of sugar (photosynthate) in a plant

Activity 1

1 Write a sentence or short paragraph to answer each of the following questions.

a How does water enter the roots?

b What causes water to flow up the stem of a plant?

c What factors increase water loss from a leaf?

d How does having needle-like leaves cut down on water loss by transpiration?

e What is the difference between phloem tubes and xylem vessels?

2 Complete the following sentences:

a Photosynthesis is the process where a plant uses __________ energy to change carbon dioxide and water into __________ and oxygen.

b The stomata are the __________ that allow gases in and out of the leaf.

c Plants photosynthesise during the __________ and transpire during the __________ and __________.

d Plants change sugars into __________, which is stored in storage organs.

e The two transport tissues are called phloem and __________. The first one carries __________ around the plant while the second carries __________ and dissolved minerals in an __________ direction.

f __________ is the loss of water from the surface of the leaf by evaporation.

3 The diagram shows an experiment set up to investigate water loss and water uptake by a green plant. The roots were carefully washed before placing the plant in the measuring cylinder. The experiment was weighed at the start of the investigation and again 24 hours later.

The scale on the measuring cylinder was used to read the volume of water before and after the 24 hour period. The table shows the results.

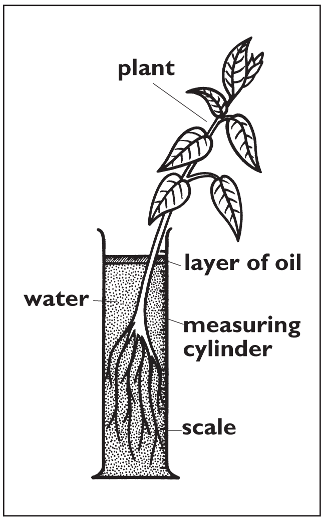


Figure 8.6 Experiment to investigate water loss

	Mass of the equipment containing the plant (g)	**Volume of water in the measuring cylinder (cm^3)**
Start of investigation	220	100
24 hours later	210	88

a Calculate the loss of mass due to water loss during the 24 hour period.

b Calculate the mass of water that has been absorbed by the roots during the 24 hour period.

c Explain why your answers to **a** and **b** are similar.

d Explain why the amount of water absorbed by the roots is not exactly the same as the amount of water lost by the plant.

e Suggest a reason for the layer of oil on the water in the measuring cylinder.

f Explain why a plant growing in a forest would not lose the same mass of water on each of several days.

g A plant growing in a forest might, under certain conditions, lose far more water than it absorbs by the roots. Describe the effect this would have on the plant.

4 Put the following statements under the appropriate heading in the table.

Carry sugars away from the leaves
Long tube-like cells
Sides of cell walls strengthened with lignin
The cells of these vessels are alive
These vessels are dead
Use energy provided by companion cells
Wood is made mostly from these cells.

Xylem	**Phloem**

Unit 9

History Of Planet Earth

Learning outcomes

On completing this unit you should be able to:

- ☐ State the age of planet Earth
- ☐ Describe the types of events that have shaped the crust
- ☐ Outline the processes involved in different types of events
- ☐ State the type of evidence used to identify and date past events
- ☐ Distinguish between direct and indirect scientific evidence

An ancient planet

Geologists have discovered that Earth is an ancient planet. Over 4 500 million years ago a huge cloud of gas and dust in the solar system contracted under gravity, then condensed and solidified to form a **protoplanet**.

As further contraction occurred, the planet heated up and began to melt. As heat was lost out into space, the planet began to cool. Eventually the surface of the planet cooled sufficiently and solidified into a crust. Steam that escaped from the crust into the atmosphere condensed into water, which filled hollows in the crust to form seas and oceans.

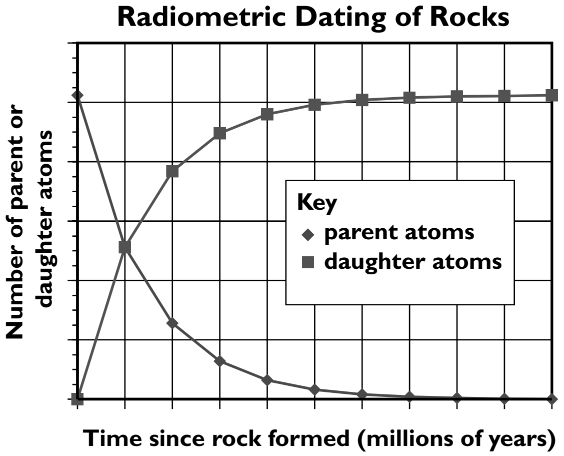


Figure 9.1 Radiometric dating of rocks

The oldest rocks on the planet have been dated at just over 4 000 million years old. These rocks were formed when sediment eroded from the original crust.

The actual age of rocks can be found by using **radiometric dating**. This involves measuring the ratio of certain atoms that are involved in **radioactive decay**. The parent atoms break down into daughter atoms at a steady rate. The ratio of daughter to parent atoms indicates how long ago the rock was formed. *Rocks have built-in clocks!*

The changing earth

Since Earth's crust first hardened, many geological events have reshaped it.

These events include sea level changes, the rising and sinking of land, magma rising through volcanoes, earthquakes, collisions within the crust and by meteorites, as well as the deposition of sediments.

Most of these events occurred before humans observers existed, but indirect evidence comes from the location and dating of rock types, as well as sequences of rock strata and the fossils present.

Earth's history

The 4 550 million years of Earth's history has been divided up into **geological periods**, each defined by the set of species present.

The longest period was the Precambrian, which stretched from Earth's beginning until 570 million years ago. Simple organisms first appeared about 3 500 million years ago. These organisms included bacteria, then unicellular algae capable of photosynthesis.

Early in the Cambrian, a wide variety of multicellular plant and animal designs **evolved** from those simple organisms. Since then, vast numbers of **species** based on the surviving designs have evolved, only to eventually become extinct. Periods often ended with a **mass extinction**, then new collections of species rapidly evolved.

The chart shows the different periods and their duration in millions of years (my). You do not need to know the order or names of the periods. But you should be aware that each period of Earth's history had a distinct **flora and fauna** (set of plant and animal species). These sets have been identified from the **fossil record**.

Period	**Interval (my)**	**New Life Forms**
Precambrian	4550–570	bacteria, unicellular algae
Cambrian	570–510	invertebrates – shellfish, trilobites
Ordovician	510–439	corals, vertebrates – jawless fish
Silurian	439–408	simple land plants
Devonian	408–362	amphibians, insects, bony fish
Carboniferous	362–290	reptiles, tree ferns, winged insects
Permian	290–245	conifers
Triassic	245–208	dinosaurs, mammals
Jurassic	208–145	birds
Cretaceous	145–65	primates and flowering plants
Tertiary	65–1.65	mammal grazers and carnivores
Quaternary	1.65 to now	modern humans

Climate and sea levels

When the average **global temperature** is cooler for long periods of time, the polar ice caps spread and glaciers advance. As much of the planet's water is locked up, the sea level falls. Extended periods with low global temperatures are called Ice Ages.

Evidence of global temperature changes comes from ice cores obtained by drilling deep into the polar ice caps. Each layer in a core is formed by snow that fell in one particular year. The average temperature for that year can be estimated by measuring the ratio of certain atoms. Carbon dioxide levels in the atmosphere for that year can be found by analysing gas bubbles. In the ice caps, temperature and carbon dioxide levels rise and fall together.

As global temperatures rise, polar and glacial ice slowly melt. Over long periods of time, the sea level will slowly rise.

The sea level has been rising very slowly over the last 7000 years. There has been a slightly more rapid rise over the last century, and some scientists link this to **global warming** caused by rising CO_2 levels in the atmosphere, however there is debate over this.

Meteorite impact

Meteorites are rocks from space that penetrate the atmosphere and collide with the crust. Most meteorites were formed at the birth of the Solar System. Shooting stars are small ones which burn up in the atmosphere.

Craters are formed when very large meteorites hit. Most meteorites hit early in Earth's history and the craters have long since worn away. Sites can be located if remnants of the meteorite are found, or from shocked quartz crystals in the rocks surrounding the original impact site.

There are only a few meteorite craters visible on Earth. But the moon, with no protective atmosphere or weathering processes, is pockmarked with craters.

A huge meteorite impact caused the extinction of the dinosaurs.

The mobile crust

The crust that forms continents continues on under the sea floor to encircle the planet. The crust has cracked into a dozen or so huge pieces called **tectonic plates**. The cracks are called **plate boundaries**.

Plates of the Crust

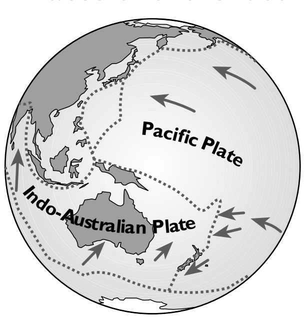


Figure 9.2 Plates of the crust

The plates 'float' on a semi-molten layer near the top of the mantle and are shunted a few centimetres each year by huge **convection currents**. These currents are caused by heat generated deep inside Earth.

Neighbouring plates are forced apart along mid-ocean ridges. Magma wells up through the cracks along the plate boundary to form new sea floor. This process is called **sea floor spreading**.

In other locations, plates grind slowly past each other. **Seismic activity** (earthquakes and tsunami) occurs when sections of two plates under tension slip suddenly past each other. This type of boundary runs the length of the South Island of New Zealand along the Main Divide.

When plates slowly collide, crumpling occurs causing **mountain building**. Usually one plate is forced (**subducted**) under another. In the North Island of New Zealand, part of the Pacific plate is being subducted under part of the Indo-Australian plate.

When crust is forced down towards the mantle it melts into magma, which rises to cause volcanic activity.

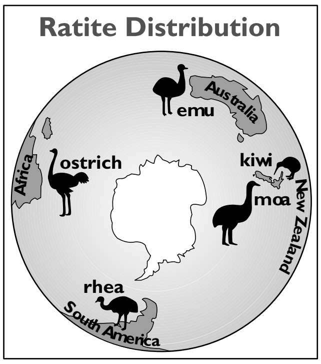


Figure 9.3 Ratite distribution

Past volcanic activity

Evidence for past volcanic activity comes from **rock strata**. Layers of volcanic rock (such as basalt) form as new lava flows solidify on top of older ones. Intervening ash layers result when ash from volcanic clouds settles.

Volcanic rock can be aged using radiometric dating.

Plate movement

Evidence for the movement of plates comes from a variety of sources: patterns in the distribution of rocks and fossils, the fit of continents, sea floor magnetic patterns and actual measurements.

The coastal shapes of Brazil and West Africa show a remarkable fit. There are also patterns in the distribution of rock and fossil types that continue across both continents.

Southern continents contain many related animal species that could not have swum from one continent to another, which is indirect evidence that the continents were once united.

Magnetic patterns in oceanic crust on either side of mid-ocean ridges form mirror images, indicating that crust on each side is moving apart.

Laser measurements from locations on either side of plate boundaries provide direct evidence of motion.

The formation of the Sāmoan Islands

In early 2000 American marine geologists confirmed the existence of an active underwater volcano east of Sāmoa. The volcano, named Vailuluʻu, rises almost five kilometres from the sea floor, with its top reaching within 610 metres of the surface. The cloudy water billowing from the volcano's summit stretches out for more than eight kilometres in all directions. The location of Vailuluʻu, about 45 kilometres east of Taʻu island, provides some new evidence in an old debate about the origin of the Sāmoan Island chain.

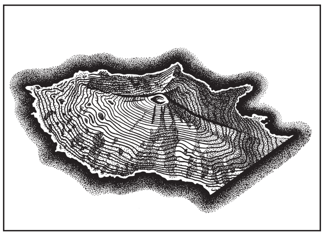


Figure 9.4 Vailulu'u volcano, Sāmoan hotspot

The Hawaiian Islands are the classic example of the 'hot spot model'. Vailuluʻu is new evidence that the Sāmoan Islands formed in the same way.

Volcanoes form underwater in two different ways. The most common occurs at mid-ocean ridges where tectonic plates meet. When the plates drift apart, magma from the Earth's mantle rises to fill in the gap, sometimes forming a volcano. Some geologists argue that the origin of the Sāmoan chain is related to rifting or crustal plate activity in a nearby ocean ridge, the Tonga Trench.

The other option is called the **hot spot model**. In this model, volcanic eruptions do not occur where plates meet but rather where they pass over 'hot spots' – areas on the sea floor where magma rises up through weak crust and bursts through a tectonic plate. As the plate continues to move, it leaves a trail of volcanoes. The Hawaiian Islands are the classic example of a hot spot chain.

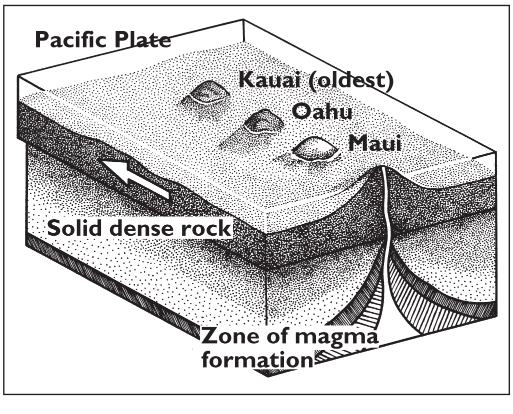


Figure 9.5 Pacific plate

The question is, are the Sāmoan islands a hot spot chain or the more common, mid-ocean ridge volcanoes? The marine geologists say Vailuluʻu is evidence that the Sāmoan islands are a hot spot chain. They say that this new volcano is too far away from the Tonga Trench to be caused by crustal plate activity.

Although there still remains a lot to learn about Vailuluʻu and its past, the geologists are certain about its future. If it grows at the highest rate possible, it could be above water in 50 years. But usually volcanic activity goes in cycles so that a more reliable estimate is 500 years. The scientists have no doubt there will be a new island in the Sāmoan chain.

Activity 1

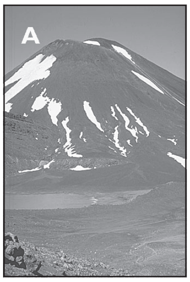
1 Match up the descriptions with the items.

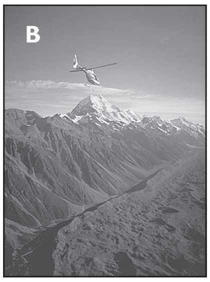
a protoplanet	**A** modification of a species or formation of a new species
b radiometric dating	**B** large number of species become extinct at the same time
c radioactive decay	**C** large rock from space which collides with the crust
d geological period	**D** average annual temperature over the entire globe
e evolve	**E** crumpling up of the crust when plates collide
f species	**F** junction between neighbouring plates
g mass extinction	**G** early stage in the formation of a planet
h flora and fauna	**H** current in a liquid caused by heated matter rising
i fossil record	**I** similar organisms capable of breeding with each other
j global temperature	**J** dating rocks by the ratio of daughter to parent atoms
k global warming	**K** earthquakes and tsunami
l meteorite	**L** atoms which can break down releasing radioactivity
m tectonic plates	**M** collection of plant and animal species present
n plate boundary	**N** interval of Earth's history with unique flora and fauna
o convection current	**O** distribution of fossils in different rock strata
p seismic activity	**P** gradual increase in the average global temperature
q mountain building	**Q** layers of rock with different minerals and fossils
r rock strata	**R** huge plates that the crust is broken up into

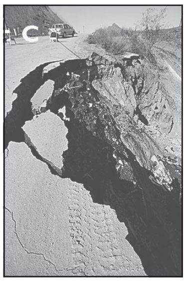
2 Explain the difference between:

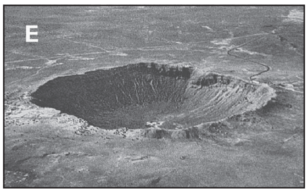
- **a** condensing and solidifying
- **b** unicellular and multicellular
- **c** evolution and extinction
- **d** flora and fauna
- **e** ice cap and glacier.

3 Identify the main geological event that has modified the crust shown in each photo.









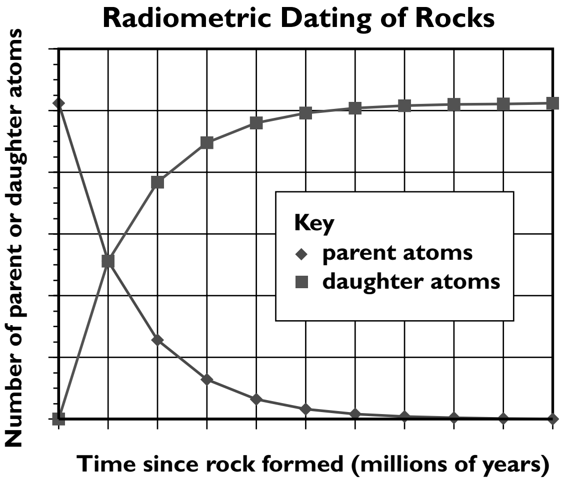
4 Decide whether these statements are true or false. Rewrite the false ones to make them correct.

- **a** Earth is a relatively young planet.
- **b** Crust formed when the planet cooled.
- **c** Oceans formed when steam in the atmosphere condensed into water.
- **d** The age of rocks can be found from the ratio of parent atoms to daughter atoms formed by radioactive decay.
- **e** Earth's crust is unchanging.
- **f** Geological periods are identified by the fossil flora and fauna present.
- **g** Mass extinctions have occurred at the end of most geological periods.
- **h** Global temperatures are falling.
- **i** Sea levels are currently rising.
- **j** Few meteorite craters are visible on Earth because of weathering.
- **k** At mid-ocean ridges new crust is being formed.
- **l** Colliding plates can cause mountain building.

5 Most rocks were formed millions of years ago. Radiometric dating is used to determine the age of rocks.

- **a** What happens to radioactive atoms when they decay?
- **b** What else is released during the decay process?

The graph compares the number of certain parent and daughter atoms present in a rock over a long time interval.



- **c** Describe the shape of the curve for the parent atoms.
- **d** Measure the height of two successive plots for the number of parent atoms. What happens to the number of atoms?

e Describe the curve for the number of daughter atoms.

f If the number of parent atoms was high compared to daughter atoms, would the rock be old or young?

g If a rock was old, would there be more parent or daughter atoms?

h What happens to all parent atoms finally?

Figure 9.8 Moon surface

6 Observe the moon image, then answer the questions.

a What type of event has caused the craters on the surface of the moon?

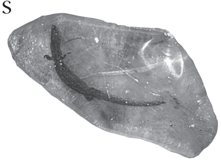
b Why has Earth been hit by far fewer meteorites?

c Why have the craters on the moon not worn away?

d Where would the meteorites that struck the moon have come from originally?

7 Use the chart on page 55 to identify the period in which these types of organisms first appeared in the fossil record.

a reptiles



b flowering plants

c trilobites

d winged insects

e shell fish

8 Explain why inhabitants of low-lying islands (such as the Maldives Islands off the coast of India) are concerned about the increasing level of carbon dioxide gas in the atmosphere.

9 Read the passage below, then answer the questions that follow.

The dinosaurs' unlucky star

Dinosaurs first appeared in the fossil record about 245 million years ago. They flourished for 180 million years before disappearing at the Cretaceous–Tertiary boundary.

Scientists have puzzled about what caused the dinosaurs' disappearance. Most theories assume the environment changed beyond the limits that dinosaurs could tolerate.

The theory with most support is that an asteroid struck 65 million years ago.

The huge explosion when the asteroid hit would have lit vast fires and thrown enormous clouds of ash high into the atmosphere. This would have reduced the amount of light reaching Earth.

With less radiant energy arriving, global temperatures would have fallen. Photosynthesis in plants would have been severely limited by the low light and cold temperatures. Much of the vegetation would have died.

Herbivores would have starved from lack of food, as would the carnivores which fed on them.

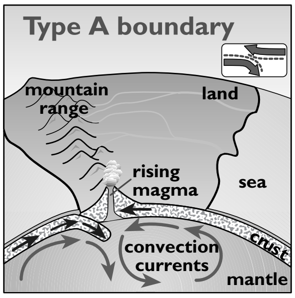
Evidence to support the theory comes from the discovery of high levels of iridium atoms as well as heavy chromium atoms in rock at the Cretaceous–Tertiary boundary. Iridium is very rare on Earth and heavy chromium atoms nearly non-existent, but both are abundant in asteroids.

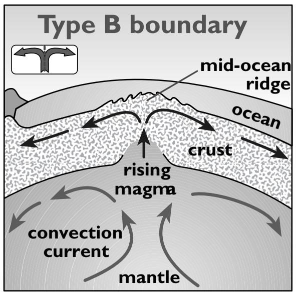
A fragment of the asteroid has been found.

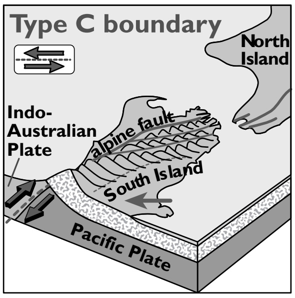
So the extinction of the dinosaurs may have been due to an extraterrestrial object!

a What period did the dinosaurs first appear in? (see page 55)
b When did the dinosaurs disappear from the fossil record?
c With the asteroid theory, what factors could have contributed to the dinosaurs' extinction?
d What immediate effects would the asteroid have had on Earth?
e How would global temperatures have changed as a result of the asteroid?
f Why would most dinosaurs have died some time after the asteroid struck?
g What evidence is there to support the asteroid theory?

10 The diagrams show different types of plate boundaries. For each diagram describe:







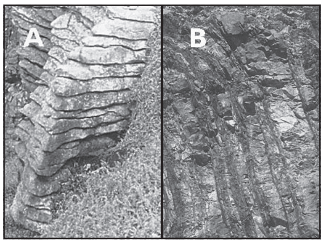
a how plates are moving relative to each other
b where this type of plate boundary would be found
c what events occur as a result of plate movement

11 By applying the principles below you can interpret sedimentary rock sequences.

- ☐ Sediments are deposited in horizontal layers.
- ☐ The bottom layer is formed first.
- ☐ Rocks with the same fossils are the same age.

Study the sequences, then answer the questions.

a How many layers are visible in photo A?
b Which layer in photo A is the oldest?
c Why is it difficult to identify the youngest layer in B?
d The layers in photo B lie at an odd angle. What process could have caused this?



e Sedimentary rocks are formed on the sea floor. How do they get to be above sea level?

12 The picture illustrates one theory about the formation of the Sāmoan Islands. Use the picture to answer the following questions.

a What is the name given to the area under the Vailuluʻu volcano.

b Which island is the oldest? Give a reason for your answer.

c In which direction is the plate on which the Sāmoan Islands sit moving?

d After a volcano emerges from the sea, what are some of the changes it may undergo as it becomes an island?

e What will eventually happen to the Sāmoan islands if the sea level remains the same?

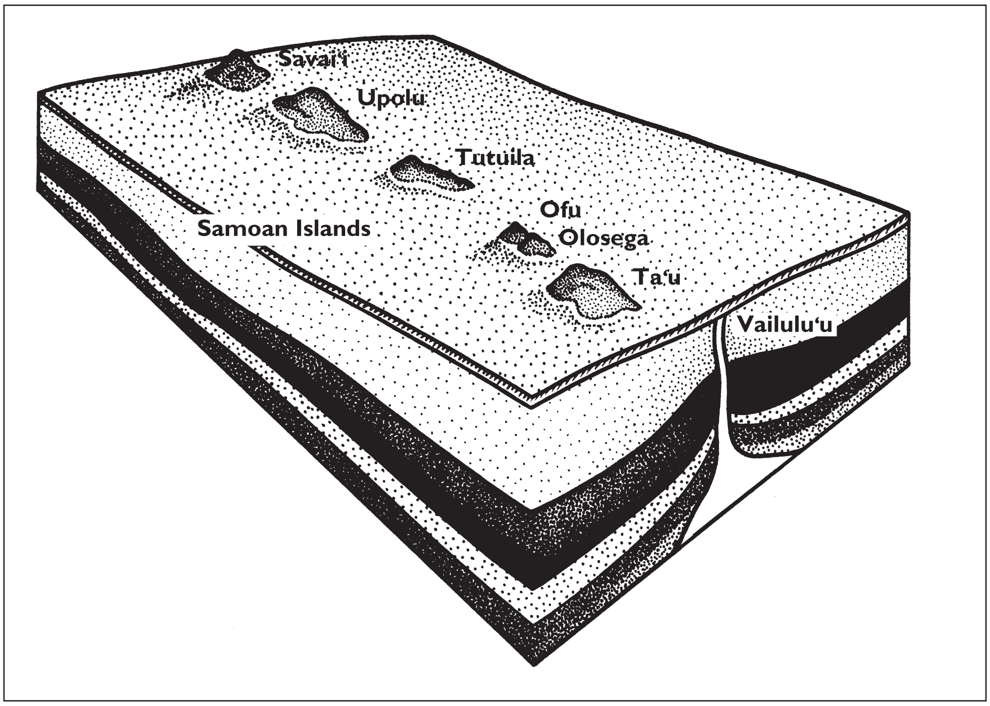


Figure 9.12 Formation of the Sāmoan islands

Unit 10

Fossil Fuels

Learning outcomes

On completing this unit you should be able to:

- ❑ Describe the composition of fossil fuels
- ❑ Describe the process of the formation of fossil fuels
- ❑ Outline the importance of fossil fuels
- ❑ Explain the chemistry of fractional distillation and cracking

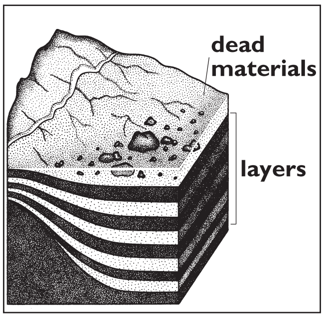


Figure 10.1 Crude oil. Parts of the dead materials change to hydrocarbons mixed with other sedimentary materials. Layers become more and more compressed as further layers settle on top

Crude oil

Crude oil (which is used to produce petrol) and natural gas are fossil fuels. They have all taken millions of years to form.

Crude oil – sometimes called petroleum – is found in some of the sedimentary rocks of the Earth's crust. Millions of years ago small animals and plants, called plankton, died and fell to the bottom of the sea. Their remains were covered by mud.

As the sediment was buried by the other sediment, it started to change into rock as the temperature and pressure increased. The plant animal remains are 'cooked' by this process and change into crude oil.

Oil is less dense than the water in the rocks and will rise, often escaping altogether if the rocks are permeable and porous.

If some of the rocks above the oil are impermeable, the oil cannot rise through these rocks and so it gets trapped underneath. These rocks are called cap rocks. The rocks that contain the oil have a high porosity and permeability and are called reservoir rocks. Geologists can often tell where oil may be trapped by looking at the structure of the rocks. Oil will tend to be trapped where rocks are domed upwards or where permeable rocks are in contact with impermeable rocks at a fault line.

Oil companies can drill down through the impermeable rocks to get it out. They are then able to turn it into products we can use.

Materials like crude oil and coal, which formed from living things many years ago, are called **fossil fuels**. Crude oil takes millions of years to form and we are using it up more quickly than it forms.

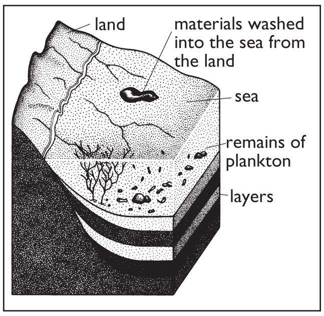


Figure 10.2 Crude oil. Layers of sediment form when sand and other materials settle on the ocean floor.

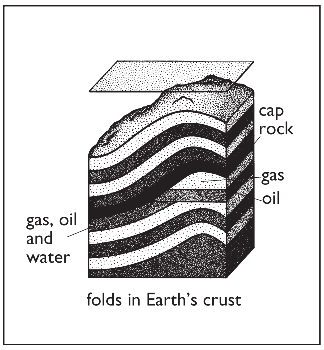


Figure 10.3 Crude oil. New material deposited as sediment forms an impervious layer called cap rock. Earth movements cause folds in the earth's crust

This is why we call crude oil a **non-renewable resource**.

Present estimates are that our supplies of crude oil will run out in about 50 years' time unless we use it more efficiently.

Processing crude oil

Crude oil must be processed before it can be used. A factory that processes crude oil is called a refinery. Crude oil is transported by pipeline or tanker to the refinery. When crude oil reaches the refinery, it is a thick, black smelly liquid. It is a mixture of hydrocarbons (chemical compounds made only of carbon and hydrogen) called alkanes.

The alkanes have a 'backbone' of carbon atoms surrounded by hydrogen atoms. Each hydrogen has one chemical bond and each carbon has four chemical bonds.

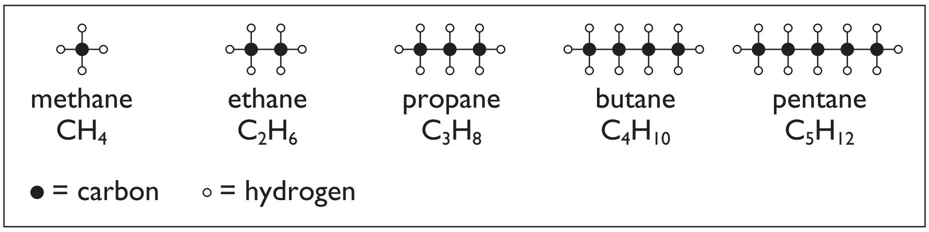


Figure 10.4 Alkanes

Crude oil contains a mixture of alkanes with carbon chain lengths that range from 4 to greater than 25. At the refinery, these different chain length alkanes are sorted out into groups of useful substances called fractions. The process of separating out the different chain lengths is called **fractional distillation** and takes place in a **fractionating column**.

Explaining fractional distillation

If you have a plate of spaghetti, the short pieces are easier to pull out than the longer pieces, which get tangled up. They are harder to separate out, just like the long molecules in crude oil.

Crude oil is heated and evaporates. It enters the fractionating column as a gas. The column is hot at the bottom and cooler at the top. This means that the longer chain hydrocarbons, with the higher boiling points turn back to liquids near the bottom.

The smaller hydrocarbons stay as gases. They rise up the column. The different fractions condense (turn back to liquids) at different heights. At the top of the column there are hydrocarbons with low boiling points. The do not condense and come out of the top as gases.

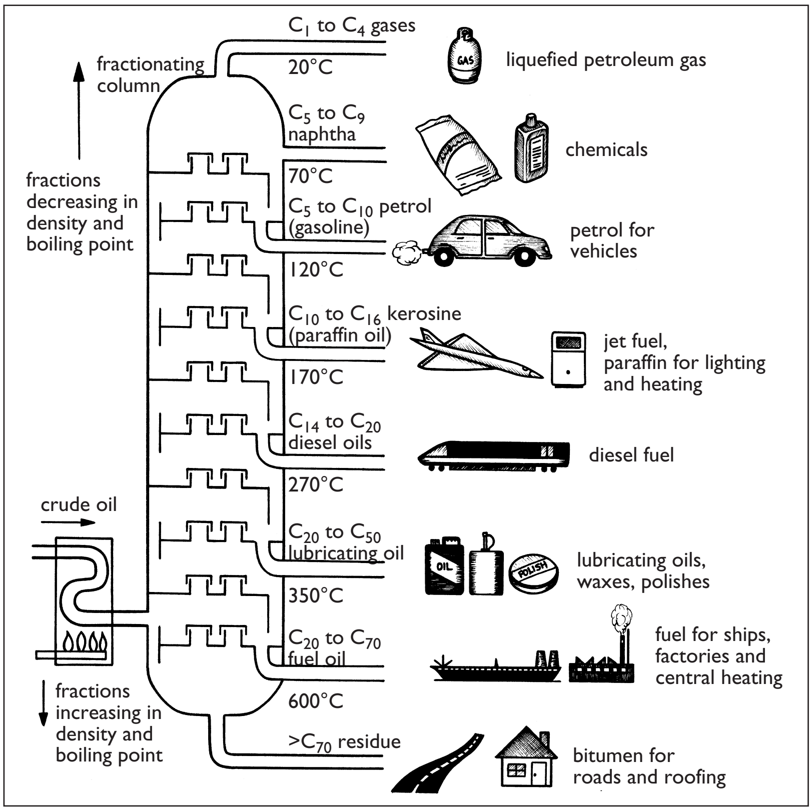


Figure 10.5 Fractionating column

Alkane	Boiling Point (°C)
Methane	–161
Ethane	–89
Propane	–42
Butane	–1
Pentane	36
Hexane	68

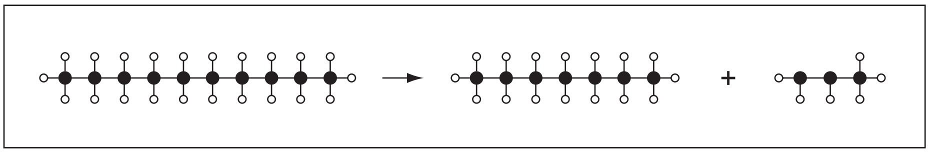
Fraction	Length of carbon chain	Use
Petroleum gases	$C_1 - C_4$	CNG LPG
Petrol	$C_4 - C_{12}$	Car fuel
Kerosine	$C_{11} - C_{15}$	Aircraft fuel
Diesel	$C_{15} - C_{19}$	Truck fuel
Lubricating oil	$C_{20} - C_{30}$	Machinery
Fuel oil	$C_{30} - C_{40}$	Ship fuel
Bitumen	C_{50} – and above	Making tar for roads

Cracking

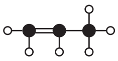
After distilling the crude oil, the oil companies find that they have too many long chain hydrocarbons. But they need more shorter chain hydrocarbons to make products like petrol, which is in high demand. Scientists have found a way to change the larger, less useful molecules into smaller, more useful ones.

The reaction is called **cracking**. The long chain hydrocarbons are broken down into shorter ones by heating them as they pass over a **catalyst**. A catalyst helps to speed up a chemical reaction. In the oil refinery this happens in a **cracker**.

When a molecule is cracked, it can form a number of products. One possibility is:



A decane (10 carbon) molecule has been broken into heptane (7 carbon) and a molecule that has the molecular formula C_3H_6. It is not an alkane. It is not saturated. Saturated means all the bonds in a compound are single bonds. To draw the structural formula of C_3H_6 there must be a double bond between two carbon atoms. Hydrocarbons that have one double bond belong to the alkene family.

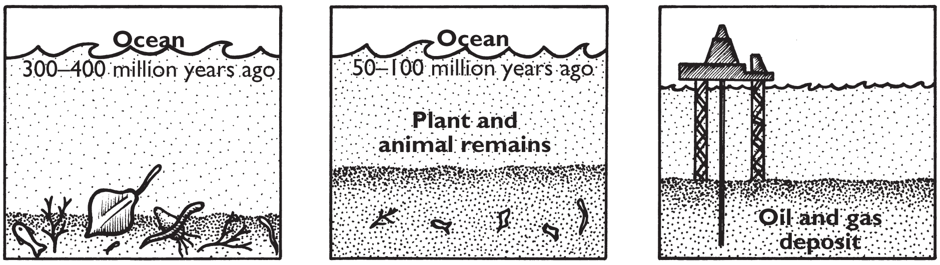
C_3H_6 or propene 

Compounds that have double bonds are called unsaturated. You may have heard of polyunsaturated oils and fats. The cracking of large chain hydrocarbons gives smaller molecules and an unsaturated hydrocarbon.

Activity 1

1 Put the following sentences about the formation and use of crude oil in the correct order.

Petroleum and Natural Gas formation



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sand and silt.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt and rock to reach the rock formations that contain oil and gas deposits.

- **a** Crude oil is transported to a refinery.
- **b** In the refinery crude oil sorted out into useful products.
- **c** More layers of sediment build up.
- **d** Oil companies drill through the rock to release the crude oil.
- **e** Plants and small animals die.
- **f** The oil is trapped by impermeable rocks and cannot escape.
- **g** The plant and animal remains are heated and change into crude oil.
- **h** The remains sink to the bottom of the sea.
- **i** The sediment turns into rock.
- **j** The temperature and pressure on the sediment increases.
- **k** They are covered in mud or sediment.

2 Copy out and complete this paragraph using the words from the list.

boiling
fractional distillation
refinery
catalyst
hydrogen
shorter
column
mixture
top

A hydrocarbon is a compound containing only (**a**) ___________ and carbon atoms. Crude oil is a (**b**) ___________ of hydrocarbons. In an oil (**c**) ___________ the crude oil is separated into its fractions by a process called (**d**) ___________ ___________. The heated oil enters the fractionating (**e**) ___________ as a gas. The hydrocarbons have different (**f**) ___________ points and condense at different temperatures. The smaller molecules, with the lower boiling points, are collected near the (**g**) ___________ of the column. Large hydrocarbons can be cracked by heating them over a (**h**) ___________. The new molecules made are (**i**) ___________ and more useful.

3 Copy and complete this table

Alkane	Formula
Methane	
	C_2H_6
	C_3H_8
Butane	
Pentane	
	C_6H_{14}
Octane	

4 Look at the boiling points in this table.

Alkane	Number of Carbon atoms	Boiling point (°C)
Methane	1	–161
Ethane	2	–88
Propane	3	–42
Butane	4	–0.5
Pentane	5	??
Hexane	6	69

a Draw a graph of their boiling points (vertical axis) against the number of carbon atoms (horizontal axis).

b What is the general pattern you see from the graph?

c Use your graph to predict the boiling point of pentane.

5 Sketch this diagram of a fractionating column. Beside each arrow fill in the fraction it represents and say what each fraction is used for.

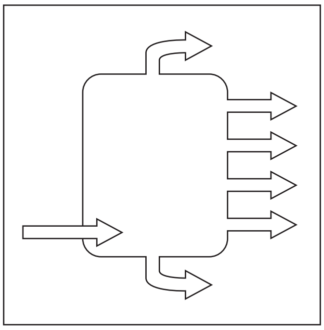
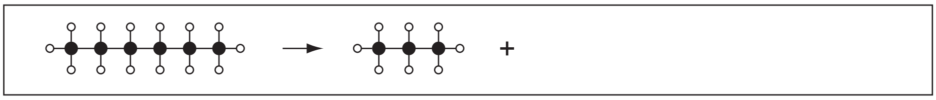


Figure 10.9 Fractionating column

6 **a** Finish off this equation.



b What is this type of reaction called?

c What are the names of the two molecules made in the reaction?

d What is needed to make this reaction happen?

e Write down the formula of each molecule in a chemical equation for the reaction.

Unit 11

Ecosystems

Learning outcomes

On completing this unit you should be able to:

- ☐ Explain the concept of an ecosystem
- ☐ Describe the way energy flows and nutrients recycle in an ecosystem
- ☐ Determine the impact of human activity on an ecosystem

The concept of an ecosystem

A **system** is a set of parts that link together to make the system work. There are inputs and outputs to the system. A car's engine is an example of a system. An input to a car is petrol and an output is exhaust gases.

An **ecosystem** is a group of living things plus the non-living things they need. The parts of an ecosystem are linked together. For example, in a forest ecosystem, rain is an input that makes the trees grow. Evaporation is an output.

There are many different ecosystems in the world. Some are **small-scale**, such as a pond, whilst others are **large-scale** and cover vast areas, such as a rainforest.

An ecosystem has a series of **stores** and **flows**. In a forest ecosystem, energy and matter is **stored** in the wood and the leaves. There is a **flow** of nutrients from the soil to the leaves. These are part of **cycles** such as the nutrient cycle and the water cycle.

Living things in the ecosystem are linked together by the flows of **energy and matter** as things eat each other. These links can be shown as **food chains**. For example:

Coconut (producer)	➔	Crab (primary consumer)	➔	Human (secondary consumer)

Lots of food chains can be linked together to create a food web.

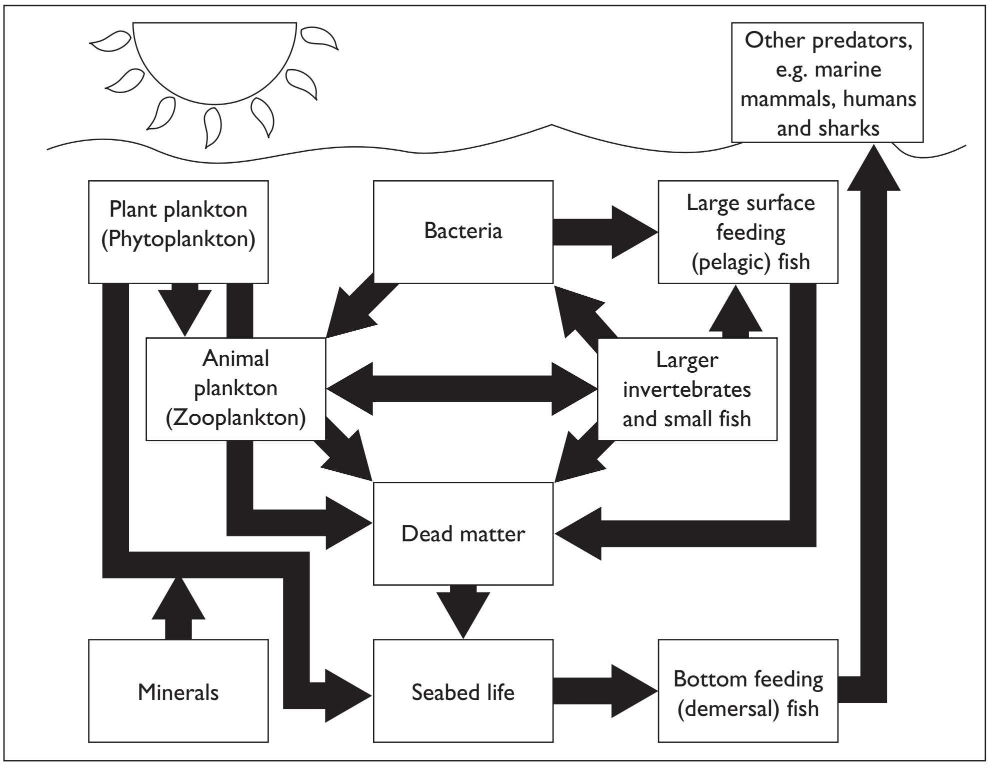


Figure 11.1 Marine food web

Energy flow in an ecosystem

Energy pyramids can be used to show what is happening in the feeding relationships in an ecosystem. These show the amount of energy transferred from one trophic (feeding) level to the next. Energy is measured in kilojoules (kJ).

At each level of the pyramid the amount of energy passed on gets less. This is because animals are using it up in their life processes. They use it to grow and move and it passes out of them with their wastes.

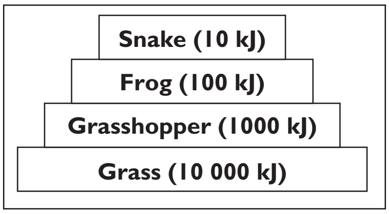


Figure 11.2 Energy pyramid

Since only some of the energy is passed on, the sharp end of the pyramid is always at the top.

The energy in all ecosystems comes from the sun. Green plants only change about 8% of the sunlight falling on to them into chemical energy during photosynthesis. This means 92% is wasted. Some is reflected from the leaf's surface while some passes straight through the leaf.

Transfer of food energy from producers to primary consumers is also wasteful. For every 100 g of plant material available, only about 10 g ends up as part of a herbivore's body. Some is not eaten, some passes out of the herbivore undigested and a lot is used in respiration to provide energy for the animal.

Similar losses in food energy occur between other trophic levels.

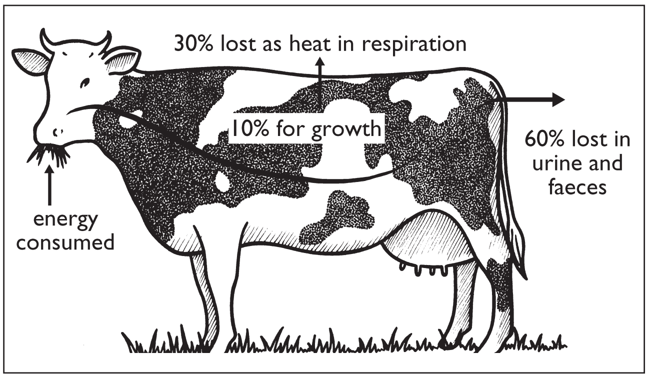


Figure 11.3 Energy budget of a cow

Nutrient flow in an ecosystem

When plants and animals die their bodies rot away or **decompose**. The bacteria and fungi that are responsible for decomposition are called decomposers. They also break down the waste materials made by animals (faeces and urine).

Plants need chemicals called nutrients for growth. These are usually found in the soil. Decomposers act as a link. By decomposing dead plant and animal remains, they free up the nutrients that were locked inside. These nutrients can then be used again by other living things.

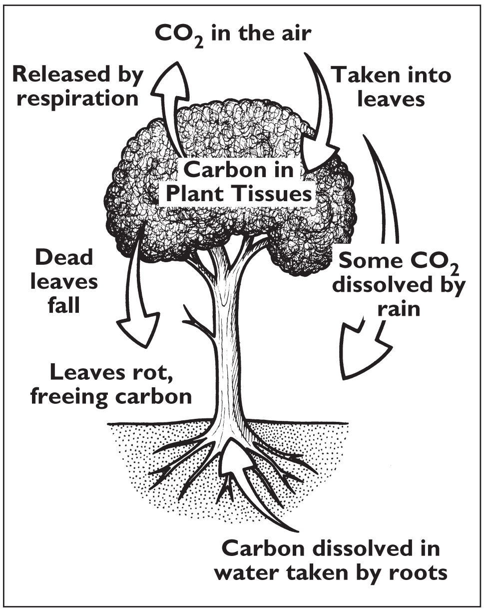


Figure 11.4 The carbon cycle

The nutrients are released into the soil and are taken up by plants. The nutrients are then passed on to animals when they eat the plants. In this way the nutrients are **cycled**.

Most living matter is made up of just six elements: carbon, hydrogen, oxygen, nitrogen, phosphorous and sulfur. Living things must have a constant supply of these elements so they can make proteins, carbohydrates and fats.

The carbon cycle

The carbon that living things need comes from the carbon dioxide in the air. Plants use it in photosynthesis to make food.

The carbon and other nutrients in the soil is taken up by the roots and pass up the trunk to be made into plant material, such as leaves or wood.

Animals get the carbon by eating plants. Carbon dioxide is released back into the air by respiration, decomposers and the burning of fossil fuels. These processes put carbon dioxide back into the air as fast as plants remove it by photosynthesis. So the amount of carbon dioxide in the air should stay the same.

The nitrogen cycle

Plants and animals need nitrogen to make proteins. The air contains nearly 80% nitrogen but it is of no use to living things as a gas. Plants and animals cannot use it in this form. It has to be changed into nitrates before it can be used by plants. Animals get their nitrogen from plant protein when they eat plants.

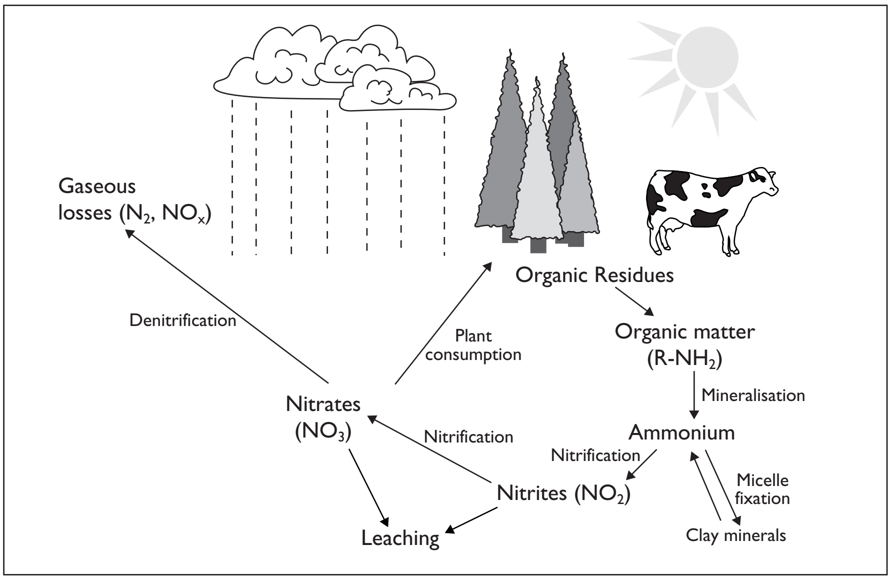


Figure 11.5 Nitrogen cycle

Decay bacteria break down dead remains and animal wastes, releasing ammonium compounds into the soil.

Nitrifying bacteria in the soil can change ammonia into nitrates.

Nitrogen-fixing bacteria are found in the soil. They convert nitrogen in the air into nitrates, which plants can take up through their roots.

Denitrifying bacteria live in waterlogged soil and swamps. They can change nitrates back into nitrogen gas.

Lightning causes nitrogen to combine with oxygen at high temperatures. The nitrogen oxides that are formed are washed into the soil by rain where they form nitrates. Some nitrates are washed out of the soil before plants can take them up. This is called **leaching**.

The rainforest ecosystem

Most rainforests are in tropical areas like Sāmoa. They have a very hot, wet climate. Temperatures can be above 24 degrees centigrade all year round and rainfall levels can be up to 2400 mm a year.

These extremes of heat and moisture mean there is an amazing variety of animal and plant life. The total **biomass** in a rainforest, including animal life, may be up to 80 000 g/m^2.

The ecosystem is well adapted to cope with the weather. For example, many leaves have drip tips to help shed water quickly. Some trees drop their leaves at the same time as growing them, so the forest looks evergreen.

The rainforests are carefully structured. The trees compete for light, which makes them grow tall (up to 50 m high). The canopy shades the ground. There aren't many plants on the forest floor because it only gets 2% of the light.

In a rainforest the vegetation looks rich but the soil is quite poor in many areas. Below the top layer of the soil, the very heavy rain over millions of years has washed away all the nutrients. Tropical soils are **not** always fertile.

The disappearing rainforest – A global environmental issue

The main problem in many rainforest areas is that big areas are being cut down. The correct word for this is deforestation. It is estimated that around the world 7.5 million hectares of rainforest are being cut down each year – that is the same as 20 rugby fields every minute.

Rainforests are being cut down for a number of reasons: to make grasslands for grazing animals; to build roads, mines and hydroelectricity dams; to harvest valuable timber; to make room for new villages and cities as the human population grows.

The consequences of deforestation

Destruction of forests increases the amount of carbon dioxide in the atmosphere and so contributes to global warming and the chances of disastrous changes in climate. This could lead to rising sea levels – a threat to the Pacific Islands.

Dense vegetation prevents heavy rains from washing away the soil. With no roots to hold the soil together, soil erosion occurs, washing away topsoil and nutrients and causing flooding downstream.

Destruction of the rainforests means the extinction of thousands of species of plants and animals that live in them.

Managing rainforest ecosystems

The obvious solution to the problems of deforestation is simply to stop people cutting the trees down. However, it's not always as straightforward as that – most of the countries that have rainforests are trying to cope with poverty, debt and high rates of population growth. Can they be blamed for trying to make some money? After all, the more economically developed world has used, and continues to use, massive quantities of natural resources. Here are some ideas for the sustainable use of the rainforest:

☐ **Agro-forestry** – a combination of farming and forestry – a mixture of different crops and trees are planted together. This variety helps prevent insect damage and soil erosion, as well as maintaining natural soil fertility.

☐ **Banning sales** of valuable hard wood, e.g. mahogany (but illegal logging may continue).

☐ **'Debt-for-Nature' swaps** – less economically developed countries could have some of their debts reduced or rescheduled in return for setting up projects to protect their rainforests.

☐ Increased world **trade in rainforest products** at fair prices.

☐ **National Rainforest Parks**, e.g. these act as wildlife reserves and may make some money by carefully managed eco-tourism.

☐ **Portable sawmills** to reduce damage caused by motor vehicles bringing logs to permanent sites.

☐ **Reserves** for local villages so that local land rights and lifestyles can be respected.

☐ **Eco-tourism ventures** so that local people can still earn an income from their land.

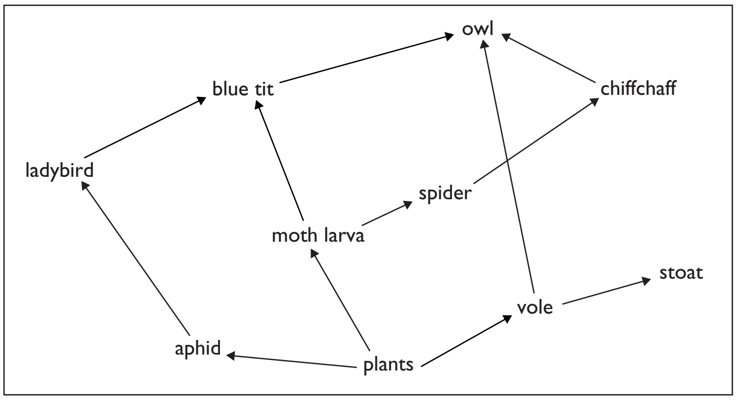
Activity 1

1 Complete the following paragraph using the words below:

biomass	chains	decomposers	food
primary	secondary	waste	webs

Producers are able to make their own **a** __________. Producers are eaten by herbivores or **b** __________ consumers. These in turn provide food for **c** __________ consumers. Dead and **d** __________ material provides food for **e** __________. Feeding relationships can be shown in food **f** __________ and food **g** __________. Feeding relationships can also be shown in a pyramid of **h** __________.

2 Use the forest food web to answer the questions that follow.



a Why do food webs begin with green plants?

b Give one example from the food web of each of these:

- **i** a producer
- **ii** a primary consumer
- **iii** a secondary consumer.

c How many carnivores are there in the food web?

d Draw a food chain from the food web with five links in it.

e If all the spiders were killed by a disease, discuss what would happen to the numbers of:

- **i** plants
- **ii** moth larvae
- **iii** chiffchaffs.

3 The table shows information about three food chains.

Producer	Primary consumer	Secondary consumer	Tertiary consumer
200 leaves (5 g)	100 caterpillars (4 g)	5 thrushes (70 g)	1 hawk (250 g)
20 water weeds (250 g)	200 insect larvae (10 g)	5 small fish (300 g)	1 otter (1 kg)
5 cabbages (300 g)	100 caterpillars (4 g)	5 thrushes (70 g)	100 fleas (0.04 g)

The average mass for the each organism is given in brackets.

a Draw a pyramid of numbers for each food chain.

b Draw a biomass pyramid for each food chain.

4 For every square metre of grass that a cow eats, it gets 3000 kJ of energy. It uses 100 kJ for growth, 1000 kJ are lost as heat and 1900 kJ are lost in wastes (faeces).

a What percentage of energy in one square metre of grass is used for growth?

b What percentage of energy in one square metre of grass passes through the gut and is not absorbed?

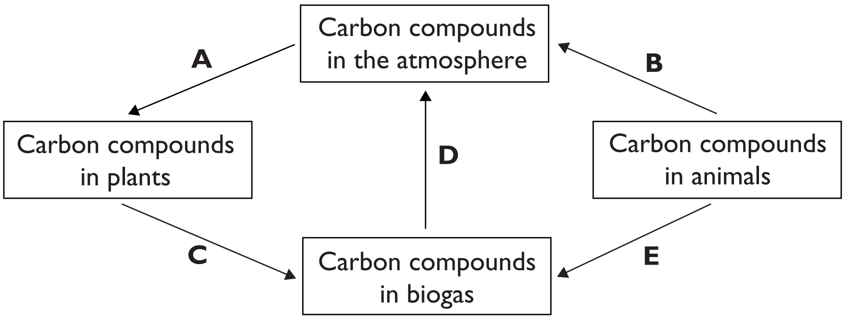
c If beef has an energy value of 12 kJ per gram, how many square metres of grass are needed to produce 100 g of beef?

5 Complete the following paragraph using the words below.

decomposers	fossil	fungi	greenhouse
increasing	nutrients	rainforest	waste

Bacteria and (**a**) __________ are able to rot down dead and (**b**) __________ materials. They are called (**c**) __________ and free up (**d**) __________ so they can be used again by other living things. The carbon dioxide level in the atmosphere is (**e**) __________. This is because humans are burning more (**f**) __________ fuels and clearing large areas of tropical (**g**) __________. Carbon dioxide is one of the (**h**) __________ gases that may be causing a rise in global temperatures.

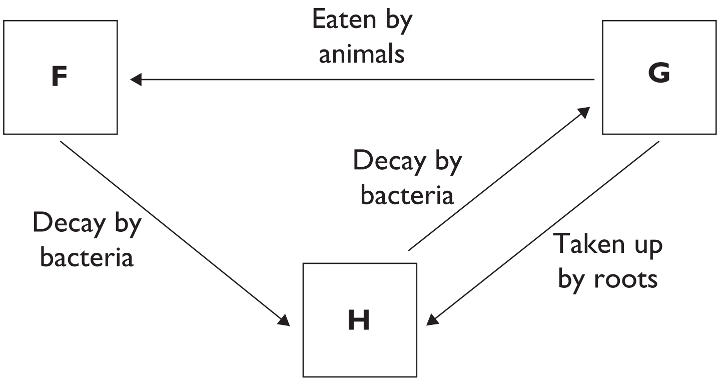
6 The diagram shows part of the carbon cycle.



a Copy the diagram and replace the letters **A** to **E** with the correct label from this list.

Respiration
Burning
Decay by bacteria
Photosynthesis

7 The diagram shows some of the ways in which bacteria help the nitrogen cycle.



Copy the diagram and replace the letters **F** to **H** with the correct labels from the list.

- ☐ nitrogen compounds in plants
- ☐ nitrogen compounds in the soil
- ☐ nitrogen compounds in animal wastes.

8 It has been estimated that between 1880 and 1980 about 40% of all tropical rainforest was destroyed, much of it by burning.

a Give three reasons why this large-scale deforestation has happened.

b Large scale deforestation is affecting the level of carbon dioxide in the air.

  i What is happening to carbon dioxide levels?

  ii How does deforestation cause a change in carbon dioxide levels?

  iii Explain some long-term effects that deforestation is likely to have on climate and soil fertility.

c Many types of habitat are being destroyed with serious effects on wildlife living there. What methods can scientists and governments use to protect this wildlife?

Unit 12

Exploring Space

Learning outcomes

On completing this unit you should be able to:

- ☐ Describe the difficulties astronomers face in studying heavenly bodies
- ☐ Explain how telescopes are used to extend our knowledge of space
- ☐ List different types of radiant energy and define the speed of light
- ☐ Discuss the problems encountered with getting a spacecraft into orbit
- ☐ State the problems involved with getting a probe to other planets

Studying space

Space is the region of the universe beyond Earth's atmosphere. Astronomy is the science concerned with the study of that space. The nature and origin of planets, moons, stars, galaxies and the universe are studied.

Astronomy relies on observation and measurement rather than carrying out experiments. It is not within our capabilities to experiment with heavenly bodies!

The task of astronomers is made more difficult by the huge distances involved. The nearest heavenly body, the Moon, is over 380 000 km away. The closest we ever get to another planet (Venus) is about 42 million km. The nearest star (Sun) is 150 million km and the next nearest (Proxima Centauri) is 40 million, million km.

It is feasible to visit planets and moons within the Solar System only, and even then the outer planets are visited only by unmanned probes as it would take too long for humans to return from those planets.

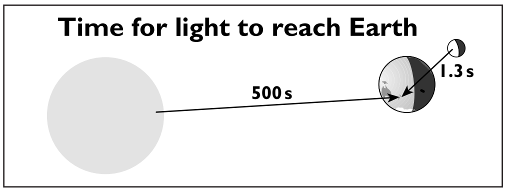
Another complication for astronomers is that their 'viewing platform', planet Earth, is moving, which gives heavenly bodies an apparent motion in the sky. Earth's daily rotation affects the position of the Moon, planets and stars in the night sky. Its annual orbit around the Sun also affects the apparent motion of the planets.

Light years away

Before rockets that could send probes to other planets were developed, astronomers relied on studying the radiant energy coming from heavenly bodies.

The most obvious form of radiant energy is light. Both planets and stars appear as pinpoints of light in the night sky.

Fortunately for astronomers, radiant energy travels very fast through space at the speed of light, which is 300 000 km/s (kilometres per second). Light takes just 1.3 s to reach us from the Moon and 500 s from the Sun.



Because of the vast distances between heavenly bodies, astronomers often measure these distances in a more convenient unit called a light year. One light year is the distance that light travels through space in one year, which is about 9 500 000 000 000 km.

Proxima Centauri, the next closest star after the Sun, is 4.2 light years away – light takes 4.2 years to reach us.

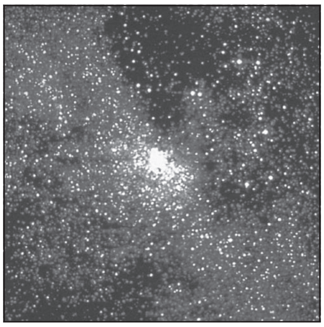


Figure 12.2 Milky Way stars

As objects get further away they become smaller in our field of view. Even a huge object such as the Sun (diameter = 1.4 million km) appears to be very small when it is 150 million km away. Planets, which are much smaller than the Sun, and other stars, which are much further away than the Sun, appear as tiny points of light.

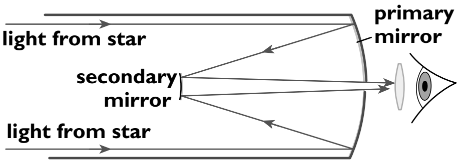
Distant objects not only appear to be very small but they are also very dim, as less light reaches us. On a clear, moonless night away from city lights you can see thousands of stars, but there are a hundred thousand million stars in our local galaxy, the Milky Way.

Observing from Earth

The Moon, stars and planets have been studied by eye alone for millennia. The pathways of heavenly bodies can be charted using simple instruments such as a compass, protractor and watch.

With the invention of the telescope, details of planets and moons could be observed, and many more stars were visible in the night sky. A light telescope is a light-gathering device, which increases the brightness of stars and the size and brightness of planets.

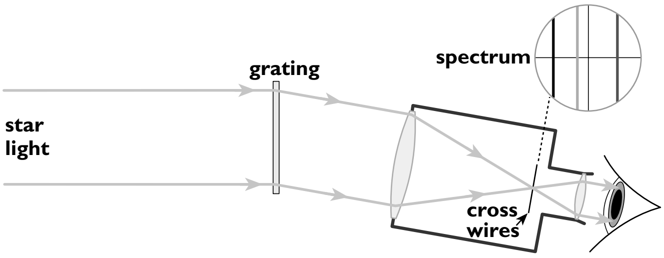
Binoculars, which are small low-powered telescopes, can also be used to reveal details about the Moon and planets close by. Cameras can be used to show the motion of heavenly bodies as star trails.



The radiant energy that comes from stars is not just light. There are other forms of radiant energy including infra-red (IR) waves, ultra-violet (UV) waves, radio waves, microwaves and gamma rays. Radio telescopes are used to collect radio waves coming from stars and distant galaxies.

Earth's atmosphere filters out most types of radiant energy other than light and radio waves (fortunately for our health), so space telescopes on satellites are used to detect far infra-red and ultra-violet waves, etc.

The light collected from a star by a telescope can be split up into a spectrum of colours for analysis using a spectrometer. Spectral colours and bright and dark lines give information about a star's surface temperature and the elements it is composed of.



From the amount that spectral lines shift towards or away from the red end of the spectrum, astronomers can tell whether a galaxy is getting closer or further away, and at what speed. This is called the red shift effect.

Getting into orbit

It is easier to study heavenly bodies from space, where there is no distortion of the light that occurs when it passes through Earth's atmosphere. The clearest images we have of heavenly events comes from the **Hubble Space Telescope**, which is a large satellite orbiting Earth.

Putting a satellite into orbit around Earth is no easy task. A huge rocket is used to propel the satellite into orbit. The satellite needs a launch speed of around 8 km/s for it to escape falling back to Earth. It must reach a certain height and be travelling in a particular direction before it can enter a stable orbit around Earth.

A satellite follows a curved path around the planet – basically the satellite falls in an endless loop that matches the curve of Earth's surface.

The power to operate space telescopes comes from solar panels that convert radiant energy from the Sun into electricity. Satellites have to cope with temperature extremes as they are exposed to, or shaded from, the Sun's intense radiant energy.

Sending probes to other planets

Other planets and their moons have been closely observed by sending unmanned space probes past them or by having probes land on them.

These probes, such as the Odyssey spacecraft sent to Mars in 2001, contain many scientific instruments. Odyssey uses an infra-red heat camera to identify minerals present in the planet's surface, and a gamma ray spectrometer to measure the amount of water present.

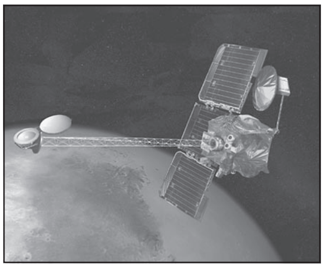


Figure 12.5 Odyssey approaching Mars

To send a probe to a planet it must first escape Earth's gravity. The escape velocity required is 11.2 km/s.

The planets are travelling around the Sun, so the trajectory of the probe must be chosen so that it will intercept the planet somewhere along its orbit. The launching pad on Earth is also in motion as Earth spins on its axis and orbits the Sun. This motion must be taken into account when planning space missions.

As a probe approaches a planet it experiences the gravitational pull of that planet. The size of the force depends on the mass of the planet and its distance away. Gravity causes the probe to accelerate towards the planet.

For the Odyssey probe to go into orbit around Mars, it had to be slowed down. First it fired its main engine, which took it into an elongated orbit. Then it used 'aerobraking' (passing repeatedly through the atmosphere of Mars) to enter a closer, circular orbit.

Activity 1

1 Match up the descriptions with the terms.

a space	**A** perceived motion due to the motion of the observer
b astronomy	**B** object that orbits a primary body due to gravity
c planet	**C** Sun and the nine planets that orbit around it
d Solar System	**D** distance light waves travel in a year through space
e apparent motion	**E** huge group of moving stars held together by gravity
f radiant energy	**F** region of the universe beyond Earth's atmosphere
g speed of light	**G** instrument for analysing a light spectrum
h light year	**H** pathway along which an object travels through space
i star	**I** study of space/ nature and motion of heavenly bodies
j galaxy	**J** electromagnetic energy waves or ripples
k telescope	**K** gigantic ball of gas burning in thermonuclear reactions
l spectrometer	**L** instrument for collecting light waves from distant sources
m red shift	**M** speed at which electromagnetic waves travel in space
n satellite	**N** launch speed required for an object to escape gravity
o space probe	**O** shift of spectral lines due to high speed of object
p escape velocity	**P** large heavenly body orbiting a star such as the Sun
q trajectory	**Q** force of attraction acting on an object due to its mass
r gravitational pull	**R** unmanned spacecraft sent to a distant planet or moon

2 Explain the difference between:
- **a** observation and experiment
- **b** planet and moon
- **c** year and light year
- **d** light and radio telescopes
- **e** telescope and spectrometer
- **f** satellite and space probe.

3 The diagram opposite shows the Southern Cross constellation, which can be identified readily in the night sky because of the two nearby bright stars called the Pointers. The brighter Pointer is called Alpha Centauri.
- **a** How fast does light travel in outer space?
- **b** How far is a light year?
- **c** If Alpha Centauri is 4.4 light years away, how long does it take its light to reach Earth?
- **d** How far away is Alpha Centauri in kilometres?

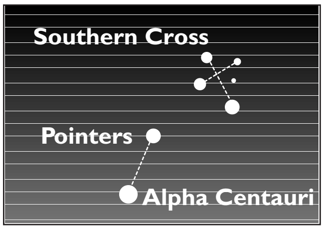


Figure 12.6 Southern Cross constellation

The brightest star that we can see in the night sky is Sirius, which is 8.6 light years distant.

e How far away is Sirius in kilometres?

4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

a Astronomy is an experimental science.

b Most heavenly bodies are located vast distances away.

c Observing the motion of heavenly bodies is complicated by the fact that the observer is always in motion too.

d Light is one form of radiant energy.

e Only light waves travel at the speed of light through space.

f If a star was 10 light years away, that would mean that the light we see today would have left the star 10 years ago.

g Distant objects appear smaller and dimmer than they actually are.

h A light telescope is basically a light-gathering device.

i Space telescopes give clear images as they are located above the atmosphere.

j To travel to another planet a probe must first reach the escape velocity of Earth.

5 The table below shows data on the planets in the Solar System. Some of the data is based on observations made using telescopes on Earth, and some is based on information obtained from probes sent to the planets. The planets are listed in order of increasing distance from the Sun.

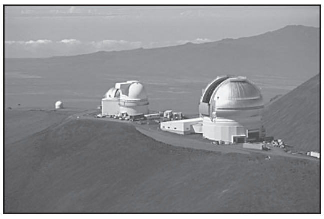
a What happens to the period (orbit time) of the planets the further away they are from the Sun?

b What happens to the mean (average) surface temperature of the planets the further away they are from the Sun?

c Suggest a reason for your answer to question **b**.

d Describe the relationship between the number of moons a planet has and the size of that planet.

Planet	Mean Distance to Sun (million km)	Diameter (000 km)	Period (years)	Mean Surface Temp. (°C)	Moons of Planet
Mercury	57.9	4.9	0.2	+427	0
Venus	108.9	12.1	0.6	+480	0
Earth	149.6	12.8	1.0	+22	1
Mars	227.9	6.8	1.9	–23	2
Jupiter	778	143.9	11.9	–150	16
Saturn	1427	120.5	29.5	–180	17
Uranus	2870	51.1	84.0	–214	15
Neptune	4497	50.5	165.8	–220	8
Pluto	5900	2.3	247.7	–230	1



6 The top photo shows the main optical (light) telescope (structure on the right) of the Gemini North Observatory high up on Mauna Kea in Hawaii.

The bottom illustration shows the Hubble Space Telescope orbiting high above Earth.

- **a** State two reasons why Earth-based telescopes are usually located in mountainous areas.
- **b** How would the Gemini telescope be lined up with a particular star?
- **c** When would astronomers not be able to use the Gemini telescope?
- **d** The Gemini South Observatory telescope is found in Chile. What advantage would this give astronomers using the Gemini facilities?
- **e** State two advantages of having a telescope in space rather than on Earth.
- **f** What is the main financial issue associated with putting a large telescope into orbit around Earth?
- **g** How was the Hubble Space Telescope placed into orbit?
- **h** What is the function of the two large flat panels shown on either side of the Hubble Space Telescope?
- **i** How would the Hubble Space Telescope be lined up with a particular star?
- **j** What prevents the Hubble Space Telescope from falling back to Earth?
- **k** Are astronomers able to use the Hubble Space Telescope even when it is exposed to the Sun's light?

7 Read the passage below, then answer the questions that follow.

Southern Africa Large Telescope

SALT is an optical telescope being built in South Africa.

The telescope will have the Southern Hemisphere's largest reflecting mirror (diameter 11 m) for collecting faint light from distant stars. It can also collect IR and UV waves.

The telescope will be able to detect objects one billion times fainter than our eyes can see.

The huge curved primary mirror is made up of an array of 91 identical hexagonal mirror segments forming a smooth, spherical-shaped curve.

The elevation of the mirror is fixed at an angle of 37° to the horizon, but the mirror can be rotated horizontally through 360°.

Basically, instead of tracking a star across the night sky as Earth rotates, the light from the star moves across the wide mirror for about 1 hr. The point at which the star light is focused moves too, so a tracker holding smaller imaging mirrors and instruments moves to keep up.

The domed tower is used to keep the 91 mirrors in precise alignment before the telescope is rotated into position.

The fixed elevation design means that astronomers must wait until Earth's rotation brings a star into line with the telescope, but it also means that it can be built for 20% of the cost of fully steerable telescopes.

Locating SALT on the Great Karoo plateau (2000 m) will avoid light pollution and also get above water vapour in the atmosphere.

a What does the acronym SALT stand for?

b Which three types of electromagnetic waves will the telescope collect?

c Publicity material claims that the telescope could detect a lighted candle on the Moon. Why is this not possible?

d Why are identical mirror segments used?

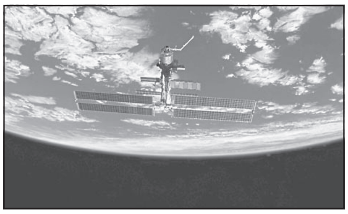
e How will astronomers point the telescope at a particular star?

f Why are the smaller imaging mirrors mounted on a mobile tracker above the main mirror?

g How does the SALT telescope differ from conventional large telescopes?

h Why is the telescope being built on a high plateau?

8 The photo shows the manned International Space Station orbiting around Earth.



The station consists of modules that are assembled in space.

a How are the modules lifted into orbit?

b How is the space station powered? What evidence can you see of this in the photo?

There is no atmosphere at the height above Earth that the station orbits.

c How are the astronauts being supplied with air for breathing?

The station moves in and out of the Sun's light as it orbits Earth.

d Why is the environment outside of the station subject to temperature extremes of up to 100°C?

e How are the astronauts protected from those temperature extremes?

Astronauts need a considerable amount of water for their daily needs.

f How is an adequate supply of water maintained?

Currently all food supplies required are transported up to the space station.

g In the future how could the space station become more self-sufficient in food supplies?

In the orbit where the station is located, the astronauts experience weightlessness, even though they are still in Earth's gravitational field.

h Why do they feel weightless?

i What negative effect could weightlessness have on the astronauts?

The space station can sometimes be seen as a bright point of light at night time.

j How could you distinguish between the station and stars?

k How could you distinguish between a shooting star and the station?

Unit 13

Inside Atoms

Learning outcomes

On completing this unit you should be able to:

☐ Draw a typical atom to show the location of the subatomic particles

☐ State the differences between protons, neutrons and electrons

☐ Describe how electrons are arranged in shells around the nucleus

☐ Define an element and explain how they are grouped on a Periodic Table

☐ Calculate the number of valence electrons of a given atom

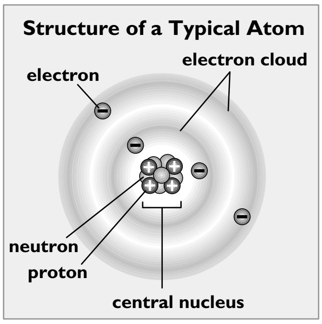


Figure 13.1 Structure of a typical atom

Building blocks of matter

The term matter is used to describe all materials found in our world. They may be solids, liquids or gases.

Scientists have discovered matter is made up of very small particles called atoms. Atoms are the building blocks of matter.

Structure of atoms

All atoms have a tiny central area called the nucleus, where nearly all the mass of the atom is concentrated. Most of the volume of an atom is empty space occupied by a few high speed objects hurtling around the nucleus.

Atoms are made of subatomic particles, and there are three types you need to be familiar with.

Protons (p or ⊕) are relatively heavy particles with a single positive electrical charge. They are packed into the nucleus along with the neutrons.

Neutrons (n or ○) have the same mass as protons, but they are uncharged and are said to be neutral.

Protons in the nucleus repel each other (like charges repel), but a strong nuclear force holds the protons and neutrons together, preventing the nucleus from disintegrating.

Mass number is the number of protons + neutrons in the nucleus.

Electrons (e or ⊖) have a single negative charge, but are much lighter than protons or neutrons. Electrons hurtle around the nucleus at very high speeds. The space that electrons move in is called the electron cloud.

Electrically neutral atoms

If an atom has equal numbers of electrons and protons, it is called a neutral atom. The negative charge on the electrons cancels out the positive charge on the nucleus.

Electron shells

Electrons travel at the speed of light around the nucleus. The attraction of the positive nucleus for the negative electrons (unlike charges attract) ensures the electrons do not escape, and the speed of the electrons ensures they are not dragged into the nucleus.

Electrons with a low level of energy are found close to the nucleus. Electrons with higher levels of energy are found further out.

The space that electrons with equal energy are found in is called an electron shell or level. Shells are centred around the nucleus.

Shells with high energy electrons enclose shells with low energy electrons, rather like layers in an Easter egg.

Electrons with a certain level of energy will all be moving somewhere within a particular shell. Although the electrons fly around the nucleus at high speed, their distance from the nucleus varies. Electrons do not travel in fixed orbits like planets around the sun.

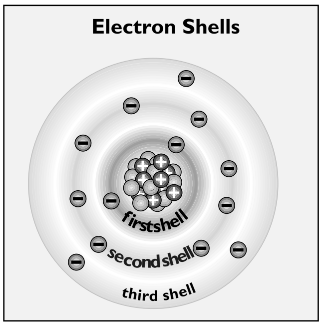


Figure 13.2 Electron shells

Filling the shells

Chemists have found that electrons prefer to be in the shells closest to the nucleus, as this involves the least energy. Electrons are lazy particles!

Only two electrons can fit in the first shell, up to eight electrons can fit in the second shell, and up to 18 in the third shell. These limits are due to repulsion between electrons (like charges repel). Electrons push each other apart so only a limited number can fit into each shell.

Electrons fill shells from the innermost shell outwards: up to two in the first, up to eight in the second and up to 18 in the third shell.

Different atoms

Atoms are not all identical. Chemists have discovered over 100 different types of atoms. Atoms can differ in their mass and size, and in how they react with other atoms.

Each type of atom has a unique number of protons in its nucleus. For example, helium atoms all have two protons, oxygen atoms all have eight and aluminium atoms 13. Different atoms have different masses because they have varying numbers of protons (and neutrons).

The number of protons in the nucleus of an atom is called its atomic number. Oxygen's atomic number is eight, neon's is 10 and aluminium's is 13.

If an atom is neutral, then its atomic number also gives the number of electrons present in the atom. So, a neutral argon atom with an atomic number of 18 will have 18 protons and 18 electrons.

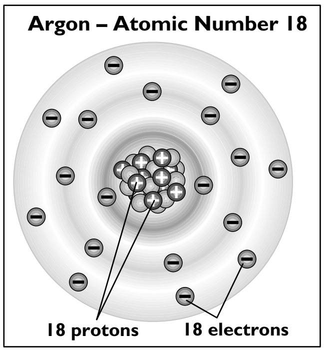


Figure 13.3 Argon

Different types of atoms also have varying numbers of electrons. The number of electrons in an atom affects the size of the atom.

The number of electrons in the outer shell of an atom affects how it reacts with other atoms. These electrons are called the valence electrons.

Each type of atom is given a particular name – oxygen, neon, aluminium, etc. Each type of atom also has its own symbol: Ne for neon, O for oxygen, Al for aluminium, etc.

Chemical elements

The substances we can see or touch are made up of huge numbers of atoms. Helium gas in a balloon, a drop of mercury and copper nails are all made of billions of atoms.

A substance made of identical atoms is called a chemical element. The helium gas, the drop of mercury and the copper nails are all examples of elements, because each contains only one type of atom. As there are over 100 types of atoms, there are over 100 elements. An element and the atoms it is made of both have the same name. The same symbol is used for an element and for its atoms.

The periodic table

Chemists arrange the elements on the Periodic Table (see page 86). The elements are placed in order, according to the atomic number of their atoms. Hydrogen is the first element, as all H atoms have one proton. Helium is the second element, as all He atoms have two protons.

The elements are placed on the table in periods (rows) from left to right. At the end of a period, the next element is placed on the following period starting from the left. The first period has two elements (hydrogen and helium). The second and third periods have eight elements in each.

This arrangement puts the metal elements on the left and the middle of the table, with the non-metal elements on the right.

A column of the Periodic Table is called a group. Elements in a group will react in similar ways. For example, helium, neon and argon in the far right group are all unreactive gases.

You need to learn the symbols of the first 20 elements in order. This order will give you the atomic numbers, e.g. the tenth element Ne has an atomic number of 10.

Activity 1 Counting valence electrons

For the first 20 elements, you need to work out how many electrons will be found in the outer shell of their atoms. The electrons in the outer shell of an atom are called the valence electrons. They are the ones involved in chemical reactions.

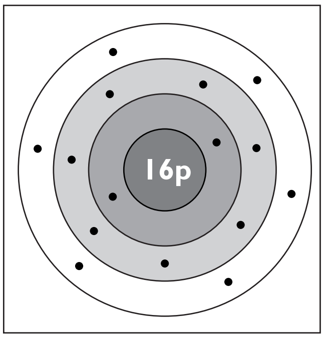


Figure 13.4 Sulfur atom

Problem:
Find out how many valence electrons sulfur atoms have.

Steps:

1. Locate the element sulfur S on the Periodic Table (see page 86) and identify its atomic number: atomic number of sulfur S is 16.
2. As an atom is considered to be neutral, the atomic number also gives the number of electrons: sulfur atoms have 16 electrons.
3. Now proceed to fill each electron shell in order until you run out of electrons.
   - **a** Put up to two electrons in the inner shell: S has two in the first shell, which leaves 14 electrons (16–2).

  - **b** Put up to eight electrons in the second shell: S has eight in the second shell; this leaves six electrons (14–8).
  - **c** Put up to 18 electrons in the third shell: S has only six electrons left to go into the third shell.

4 Finally write down the number of valence electrons: sulfur has six valence electrons.

Activity 2

1 Match up descriptions with terms.

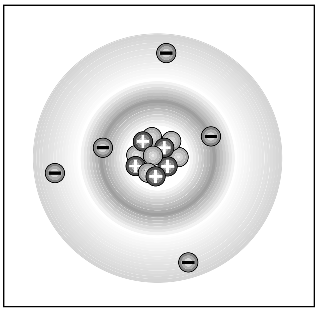
a matter	**A** atom with equal numbers of protons and electrons
b atoms	**B** particles that are uncharged or have no overall charge
c nucleus	**C** electrons in the outer shell of an atom
d subatomic particles	**D** particles with a positive charge in the nucleus
e protons	**E** central area of an atom containing protons and neutrons
f neutrons	**F** number of protons in the nucleus of an atom
g neutral	**G** very small negative particles flying around nucleus
h mass number	**H** all substances in the universe
i electrons	**I** a row of the Periodic Table
j electron cloud	**J** substance made of identical atoms
k neutral atom	**K** includes protons, neutrons and electrons
l electron shell	**L** a column of the Periodic Table
m atomic number	**M** uncharged particles in the nucleus of an atom
n valence electrons	**N** space that electrons with equal energy occupy
o element	**O** very small particles that all matter is made of
p Periodic Table	**P** number of protons and neutrons in the nucleus
q period	**Q** the space that all the electrons of an atom occupy
r group	**R** chart with elements arranged in periods and groups

2 Explain the difference between:

- **a** the nucleus and an electron cloud
- **b** protons and electrons
- **c** mass number and atomic number
- **d** atoms and elements
- **e** periods and groups.

3 Copy and complete the following table which summarises the mass, charge and location of subatomic particles.

Particle	Mass	Charge	Location
proton	heavy		
neutron			nucleus
electron		negative	



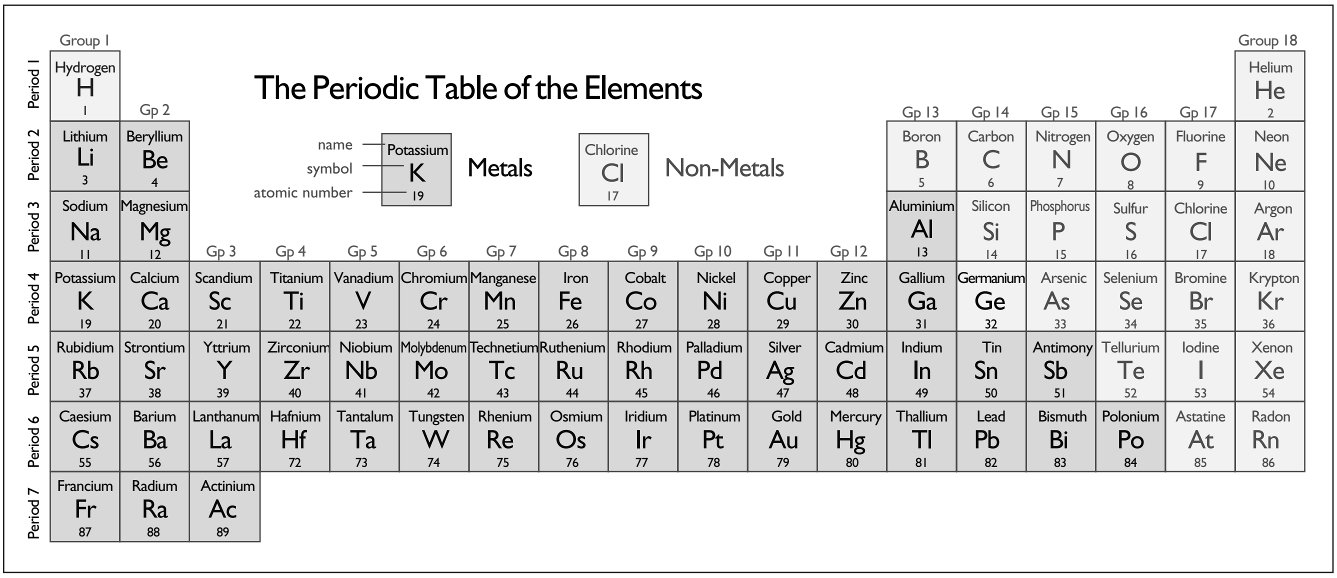
4 In this diagram of the atom all of the subatomic particles are visible.

- **a** How many protons are there?
- **b** How many neutrons are there?
- **c** How many electrons are there?
- **d** What is the atom's mass number?
- **e** What is the atom's atomic number?
- **f** Is the atom neutral? How do you know?

5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** All matter is made of atoms.
- **b** The central area of an atom is called the nucleus and the surrounding area the electron cloud.
- **c** Protons are negative, electrons are neutral and neutrons are positive.
- **d** Protons and neutrons are both much heavier than electrons.
- **e** Like charges attract and unlike charges repel.
- **f** Neutral atoms have equal numbers of protons and neutrons.
- **g** The higher the energy of an electron, the closer it will be to the nucleus.
- **h** Electron shells are filled by equal energy electrons.
- **i** Different types of atoms have different numbers of protons.
- **j** The electrons in an atom's innermost shell are called valence electrons.
- **k** An element is made of identical atoms.
- **l** Elements in a group react similarly.

6 Use the Periodic Table to find the symbols for the following elements:



The Periodic Table of the Elements

name / symbol / atomic number: Potassium K 19 — Metals

Chlorine Cl 17 — Non-Metals

	Group 1	Gp 2	Gp 3	Gp 4	Gp 5	Gp 6	Gp 7	Gp 8	Gp 9	Gp 10	Gp 11	Gp 12	Gp 13	Gp 14	Gp 15	Gp 16	Gp 17	Group 18
Period 1	Hydrogen H 1																	Helium He 2
Period 2	Lithium Li 3	Beryllium Be 4											Boron B 5	Carbon C 6	Nitrogen N 7	Oxygen O 8	Fluorine F 9	Neon Ne 10
Period 3	Sodium Na 11	Magnesium Mg 12											Aluminium Al 13	Silicon Si 14	Phosphorus P 15	Sulfur S 16	Chlorine Cl 17	Argon Ar 18
Period 4	Potassium K 19	Calcium Ca 20	Scandium Sc 21	Titanium Ti 22	Vanadium V 23	Chromium Cr 24	Manganese Mn 25	Iron Fe 26	Cobalt Co 27	Nickel Ni 28	Copper Cu 29	Zinc Zn 30	Gallium Ga 31	Germanium Ge 32	Arsenic As 33	Selenium Se 34	Bromine Br 35	Krypton Kr 36
Period 5	Rubidium Rb 37	Strontium Sr 38	Yttrium Y 39	Zirconium Zr 40	Niobium Nb 41	Molybdenum Mo 42	Technetium Tc 43	Ruthenium Ru 44	Rhodium Rh 45	Palladium Pd 46	Silver Ag 47	Cadmium Cd 48	Indium In 49	Tin Sn 50	Antimony Sb 51	Tellurium Te 52	Iodine I 53	Xenon Xe 54
Period 6	Caesium Cs 55	Barium Ba 56	Lanthanum La 57	Hafnium Hf 72	Tantalum Ta 73	Tungsten W 74	Rhenium Re 75	Osmium Os 76	Iridium Ir 77	Platinum Pt 78	Gold Au 79	Mercury Hg 80	Thallium Tl 81	Lead Pb 82	Bismuth Bi 83	Polonium Po 84	Astatine At 85	Radon Rn 86
Period 7	Francium Fr 87	Radium Ra 88	Actinium Ac 89															

- **a** fluorine
- **b** calcium
- **c** iodine
- **d** chlorine
- **e** carbon
- **f** helium
- **g** silicon
- **h** sodium
- **i** lead
- **j** zinc
- **k** potassium
- **l** nitrogen
- **m** magnesium
- **n** phosphorus
- **o** iron
- **p** mercury
- **q** copper
- **r** argon
- **s** neon
- **t** aluminium
- **u** manganese
- **v** bromine
- **w** silver
- **x** nickel

y boron **z** lithium

7 Use the Periodic Table to find the names of the following elements:

a Fe **b** Zn **c** Ag **d** S
e C **f** Li **g** Na **h** Ca
i H **j** Hg **k** N **l** I
m O **n** Mg **o** K **p** Be
q Si **r** Ne **s** Br **t** F
u Al **v** Pb **w** B **x** P
y He **z** Mn

8 Which elements on the Periodic Table have no partially filled electron shells? Where are they found on the table? How do they react with other atoms?

9 Find the names of the elements whose atoms have the following atomic numbers:

a 1 **b** 2 **c** 6 **d** 7
e 10 **f** 11 **g** 12 **h** 13
i 16 **j** 17 **k** 20 **l** 26
m 29 **n** 30 **o** 82

10 How many protons do the following atoms have?

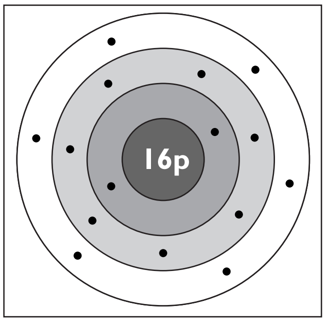
a hydrogen **b** aluminium **c** lithium **d** carbon
e calcium **f** sodium **g** magnesium **h** sulfur
i chlorine **j** nitrogen **k** fluorine **l** zinc

11 How many electrons do these neutral atoms have?

a iron **b** hydrogen **c** mercury **d** lead
e magnesium **f** helium **g** sulfur **h** carbon
i bromine **j** oxygen **k** neon **l** nitrogen

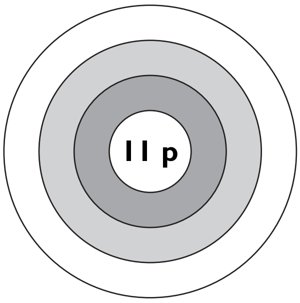
12 The following questions all relate to the periodic table of elements.

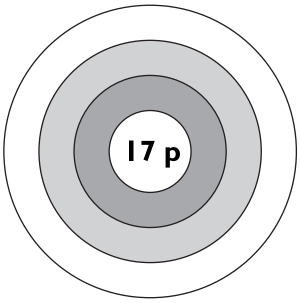
a Why is the chart called the Periodic Table?
b There are over 100 elements. How many elements are shown on this reduced version of the Periodic Table?
c How are the elements arranged on the table?
d What does the term 'period' refer to on the Periodic Table?
e Which elements are found in Period 2 of the table?
f What does the term 'group' refer to on the Periodic Table?
g Which elements are found in Group 2 of the Periodic Table?
h Which elements are found in Group 18 of the table?
i Where are the metals found on the table?
j Where are the non-metals?
k Which group of elements has atoms with completely filled shells?
l Which group has atoms with a lone electron in their outer shells?
m Which group has atoms that are one electron short of a full shell?

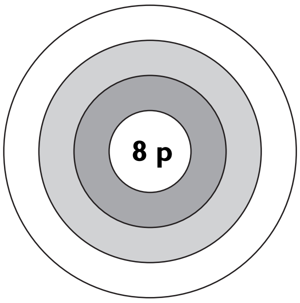


13 The diagram to the left shows the arrangement of electrons in the shells of a sulfur atom. Use the method described in the Activity 1 section on page 84 to complete similar diagrams for the three atoms below.

For each atom state the number of valence electrons it will have.

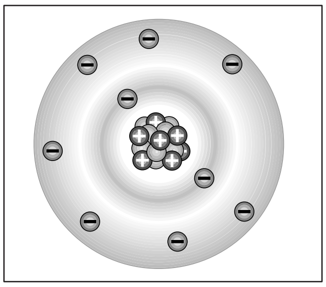






14 Copy and complete this chart.

Element	Protons	Neutrons	Mass No.
lithium	3		
carbon	6		
fluorine	9		
aluminium	13		
chlorine	17		



15 The diagram to the left shows a neutral atom (with 10 neutrons).

- **a** How many electrons does it have?
- **b** How many protons will it have?
- **c** What will its atomic number be?
- **d** What atom is it?
- **e** What is its mass number?
- **f** How many valence electrons are there?
- **g** Is the element a metal or a non-metal?

Unit 14

Atom Arrangements

Learning outcomes

On completing this unit you should be able to:

- ☐ Explain how chemical bonds hold atoms together
- ☐ Define the terms element, compound, molecule, ion and lattice
- ☐ Compare covalent and ionic bonding between atoms
- ☐ Predict the behaviour of atoms from the number of valence electrons
- ☐ Interpret the formula of molecular and ionic compounds

Bonding between atoms

Atoms are the building blocks of matter, but how are they arranged? Most atoms are found joined to other atoms, either to the same or to different types. Atoms can be joined in small groups called molecules, or in fixed arrangements called **lattices** made up of billions of atoms.

The atoms in molecules and lattices are held together by the attraction between opposite electrical charges. This attraction, which holds atoms together in definite arrangements, is called **chemical bonding**.

Behaviour of atoms

Chemists have found that atoms with full **electron shells** are **stable** and **unreactive**. Helium (2e) and neon (10e) with full shells are stable. Argon (18e) is also stable.

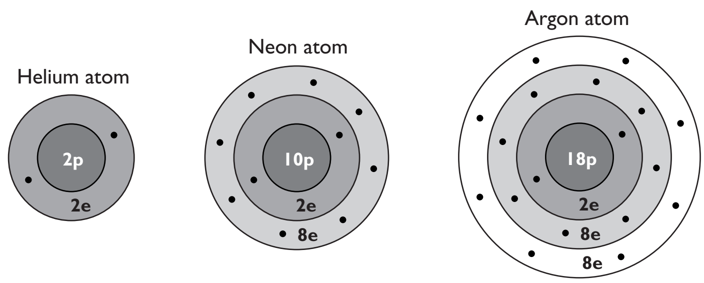


Figure 14.1 Behaviour of atoms

Other atoms react and end up with stable electron configurations. Atoms are stable if they have two, eight or 18 electrons.

Atoms with partly filled shells tend to be unstable and reactive. They can take, lose or share electrons and may reach a state with full shells.

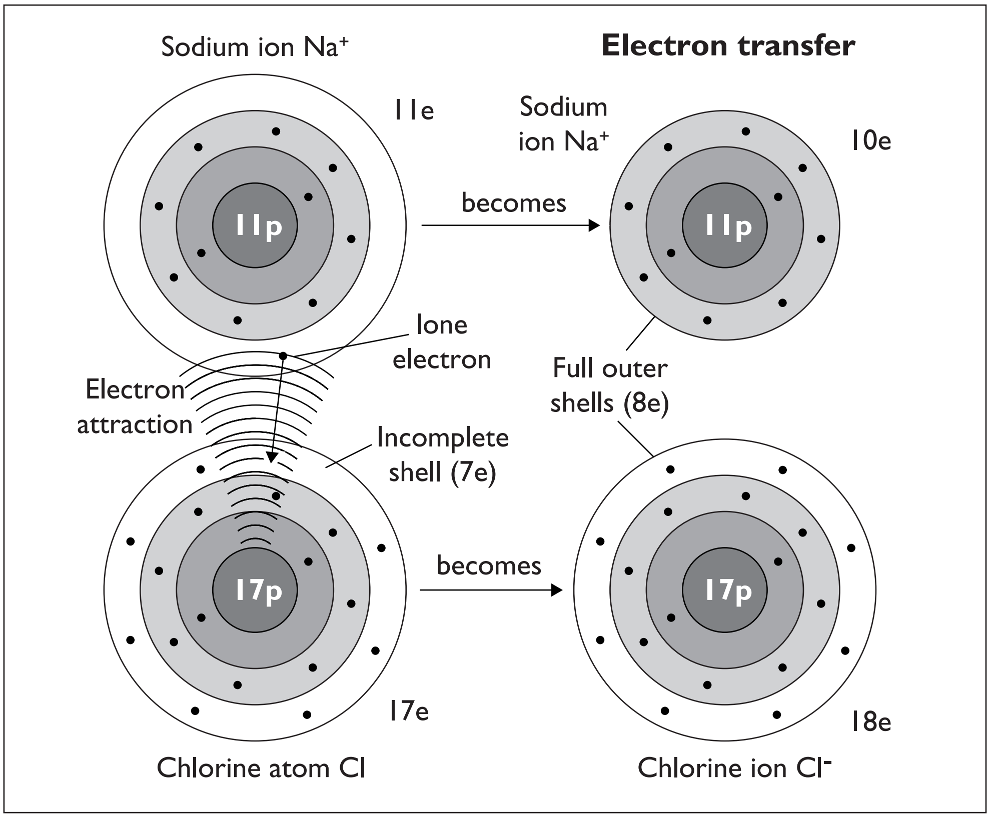


Figure 14.2 Electron Transfer

The **nuclei** of non-metal atoms (e.g. chlorine) strongly attract electrons of nearby atoms, and can pull them off weaker atoms.

Most metal atoms (e.g. sodium) have a few weakly held outer electrons and can lose them to stronger non-metal atoms. If they lose all their **valence** (outer shell) **electrons**, the atoms will be left with full inner shells.

Non-metal atoms can also attract the outer electrons of other non-metal atoms. But in this case the electrons are *shared* rather than taken.

Compounds

An **element** is a substance made of identical atoms. The atoms may be single as in helium gas, bonded in molecules as in oxygen gas (O_2) or bonded in a lattice as billions of carbon atoms are in a diamond.

Atoms can also be bonded to different types of atoms. A chemical **compound** is a substance in which non-identical atoms are bonded. Water (H_2O) is a compound where two hydrogen atoms are bonded to each oxygen atom in a molecule. Sodium chloride (table salt) is a compound with billions of sodium and chlorine atoms bonded in a lattice (see Figure 14.4).

Molecules

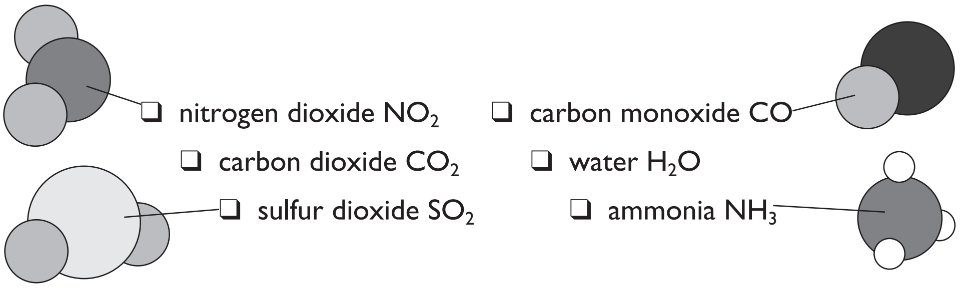
A **molecule** is a group of atoms bonded together because the atoms share electrons. A molecule has a definite number of atoms. Each atom shares some electrons with a neighbouring atom (or atoms). Non-metals form molecules.

Simple molecules are just two identical atoms. Each atom contributes shared electrons. This helps fills the outer shells of both atoms. Examples are H_2, O_2, N_2 and Cl_2 molecules.

Molecular compounds have non-identical atoms sharing electrons. In water (H_2O), the central O atom shares electrons with two H atoms. In carbon dioxide (CO_2), the central C atom shares electrons with two O atoms.

When a pair of atoms in a molecule share electrons, those electrons fly about in a space surrounding the nuclei of the two atoms. The attraction that the two positive nuclei have for those shared electrons then is the bond that holds the atoms together. *A **covalent bond** occurs when atoms share electrons.*

You should know these molecular compounds:



- ☐ nitrogen dioxide NO_2
- ☐ carbon dioxide CO_2
- ☐ sulfur dioxide SO_2
- ☐ carbon monoxide CO
- ☐ water H_2O
- ☐ ammonia NH_3

The formula gives the exact number of each type of atom in a molecule. The small number after a symbol gives the number of that type of atom (no number = 1).

Simple ions

A neutral atom has the same number of electrons as protons. The negative and positive charges balance.

If an atom gains or loses electrons, it may become stable, but the number of positive and negative charges in the atom will no longer balance; the atom becomes charged. A charged atom is called an ion.

A simple ion is just a single charged atom. The overall charge on the ion is written top right, e.g. Na^+ and $Cl^–$.

If an atom (e.g. Cl) pulls electrons off another atom (e.g. Na), it has more negative charge than positive. So it is a negative ion ($Cl^–$). The atom (Na) that lost electrons has more protons than electrons. As it has more positive charge than negative, it is now positive ion (Na^+).

Atoms gain or lose electrons and can end up with full shells. You can predict what atoms will do from the number of valence electrons they have. Non-metal atoms with nearly full outer shells take electrons; metal atoms with nearly empty shells lose those electrons.

You will need to know the formulae of these ions:

- ☐ H^+, Na^+, K^+
- ☐ Al^{3+}, Fe^{3+}
- ☐ $O^{2–}$ (oxide)
- ☐ $Mg^{2+,}$ Ca^{2+}, $Fe^{2+,}$ Cu^{2+}, Zn^{2+}, Pb^{2+}
- ☐ $Cl^–$ (chloride)

Ionic compounds

When atoms of different elements react and electrons are transferred, then atoms that gain electrons become negative ions and those that lose electrons become positive.

The positive and negative ions are attracted to each other and form a lattice. Each negative ion becomes surrounded by positive ions.

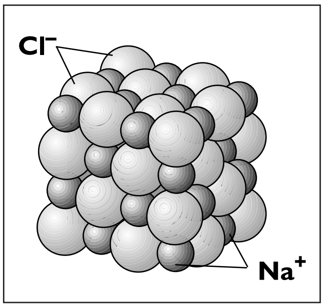


Figure 14.4 Sodium chloride lattice

The attraction between oppositely charged ions holds the lattice together. This is called ionic bonding. Substances with ionic bonds are called ionic compounds and they are neutral. Metal atoms form ionic compounds with non-metals atoms by losing electrons to them.

Ionic compounds are written with the positive ion first followed by the negative ion. Positive ions are named by adding the word ion after the name of the atom. Negative ions are often given the suffix '-ide' (e.g. oxide ion).

Examples of ionic compounds are sodium chloride (NaCl) and magnesium chloride ($MgCl_2$). The charges are not written in the formula. As ionic compounds are lattices with billions of ions, the small numbers give *the ratio of different ions, not exact numbers*. So $MgCl_2$ means one Mg^{2+} ion to every two Cl^- ions ($1\ Mg^{2+}:2\ Cl^-$).

More complicated ions

Molecules usually have no overall charge, but sometimes a molecule can have extra or insufficient electrons. These charged molecules are ions. You need to know the names and formulae of these ions:

☐ hydroxide ion **OH^-**
☐ carbonate ion **CO_3^{2-}**
☐ bicarbonate ion **HCO_3^-**
☐ nitrate ion **NO_3^-**
☐ sulfate ion **SO_4^{2-}**
☐ ammonium ion **NH_4^+**

Note that the charge is spread over the whole group of atoms.

☐ **Polyatomic ions** (ions made of more than one atom) act like simple ions when they form compounds.

☐ Examples are calcium sulfate ($CaSO_4$) and magnesium hydroxide ($Mg(OH)_2$). Again the formula gives the ratio of ions. So the formula $CaSO_4$ means one Ca^{2+} ion for every SO_4^{2-} ion. The small number after the brackets around a polyatomic ion indicates the number of that type of ion in the ratio. So $Mg(OH)_2$ means one Mg^{2+} ion to every two OH^- ions ($1\ Mg^{2+}: 2\ OH^-$).

Atom	Valence Electrons	Action	Result	Ion Formed
H	1e in 1st shell	lose 1e	all shells empty	$H - 1e = H^+$
O	6e in 2nd shell	gain 2e	2nd shell full (8e)	$O + 2e = O^{2-}$
Na	1e in 3rd shell	lose 1e	2nd shell full (8e)	$Na - 1e = Na^+$
Mg	2e in 3rd shell	lose 2e	2nd shell full (8e)	$Mg - 2e = Mg^{2+}$
Al	3e in 3rd shell	lose 3e	2nd shell full (8e)	$Al - 3e = Al^{3+}$
Cl	7e in 3rd shell	gain 1e	3rd shell full (8e)	$Cl + 1e = Cl^-$
K	1e in 4th shell	lose 1e	3rd shell full (8e)	$K - 1e = K^+$
Ca	2e in 4th shell	lose 2e	3rd shell full (8e)	$Ca - 2e = Ca^{2+}$

Activity 1

1 Match up the descriptions with terms.

a atom	**A** central area of an atom containing protons and neutrons
b lattice	**B** the attraction that holds atoms in molecules or lattices
c chemical bonding	**C** will not lose, share or take electrons
d electron shell	**D** space in which electrons with identical energy are found
e stable atoms	**E** basic building blocks of matter
f unreactive atoms	**F** substance in which non-identical atoms are bonded
g nucleus	**G** a regular array of billions of atoms or ions
h valence electrons	**H** an atom that has more protons than electrons
i element	**I** atoms which have full electron shells
j compound	**J** a group of non-identical atoms sharing electrons
k molecule	**K** substance in which atoms are held together by ionic bonds
l molecular compound	**L** an atom that has more electrons than protons
m covalent bond	**M** electrons in the outer occupied shell of an atom
n ion	**N** a charged atom or group of atoms
o negative ion	**O** group of bonded atoms that are sharing electrons
p positive ion	**P** substance made of identical atoms
q ionic bonding	**Q** occurs when two atoms are sharing electrons
r ionic compound	**R** the attraction between opposite charge ions

2 Explain the difference between:

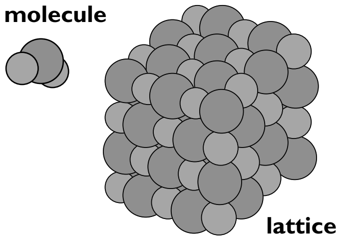
a a molecule and a lattice

b an element and a compound

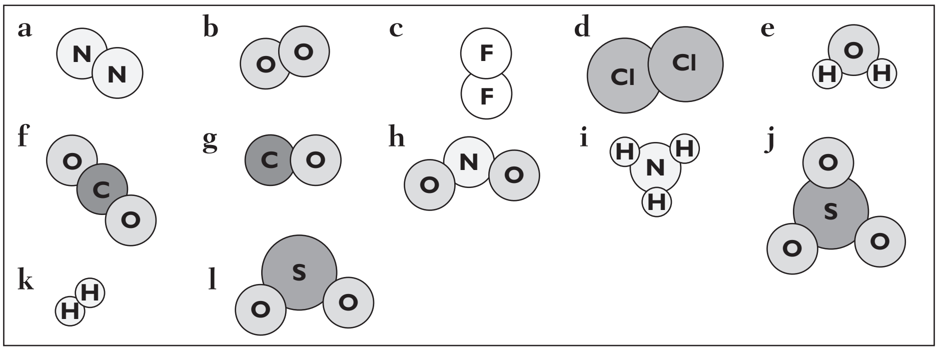
c a molecular and an ionic compound

d a covalent and an ionic bond

e a simple and a complex ion.



3 Identify the name and formula of each molecule.



m What is a molecule?

n Which of the above molecules are elements?

o Which of the above molecules are compounds?

Molecules:

carbon dioxide **CO_2**
hydrogen **H_2**
nitrogen dioxide **NO_2**
chlorine **Cl_2**
sulfur dioxide **SO_2**
oxygen **O_2**
carbon monoxide **CO**
fluorine **F_2**
ammonia **NH_3**
water **H_2O**
sulfur trioxide **SO_3**
nitrogen **N_2**

4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** Most atoms are bonded to other atoms.
- **b** A molecule is made of a limited number of atoms.
- **c** A lattice will have a fixed number of atoms.
- **d** Chemical bonds hold atoms together in molecules and lattices.
- **e** Atoms with full electron shells are stable.
- **f** Atoms can steal, surrender or share electrons to gain full shells.
- **g** Some non-metal atoms are able to pull electrons off metal atoms.
- **h** A compound is a substance made of identical atoms bonded together.
- **i** Metal atoms can form molecules.
- **j** A covalent bond is due to sharing of electrons between atoms.
- **k** Ions are made when electrons are transferred between atoms.
- **l** Ionic bonding is due to the attraction between same charge ions.
- **m** Metal atoms form compounds with non-metal atoms.

5 If a formula contains only non-metal atoms, then it is a molecule. Use these guidelines to interpret the formulae below:

Interpreting a molecular formula

- ❑ the formula specifies the exact number of types of atoms
- ❑ symbols give the types of atoms present
- ❑ small numbers after a symbol give the number of atoms
- ❑ no number after a symbol means only one of that atom

e.g. **NO_2**

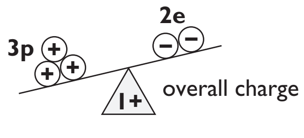
NO_2 has 1 nitrogen atom and 2 oxygen atoms

a CO_2
b H_2O
c O_2
d CO
e O_3
f Cl_2
g NO_2
h N_2O_5
i HCl
j NO
k NH_3
l CH_4
m SO_2
n SO_3
o S_8

6 Use the method below to find the overall charge on the following ions.

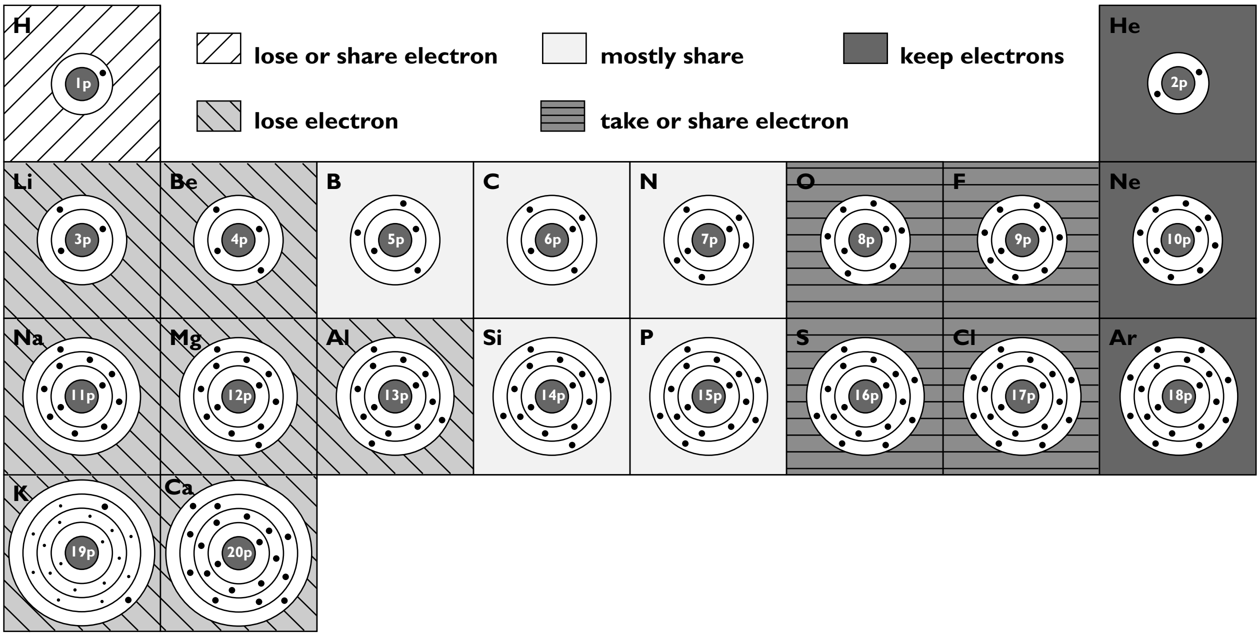
Finding overall charge on an ion

1. Find the number of protons from atomic number on Periodic Table (e.g. Li has 3p).
2. Number of electrons = number of protons in a neutral atom (Li atom has 3e).
3. Calculate number of electrons present in the ion (Li loses 1 so it is left with 2e).
4. Draw a seesaw diagram of protons and electrons in ion.
5. Calculate the overall charge on ion from difference in charge (1+ for Li ion = Li^+).



a F atom gains 1 electron
b O atom gains 2 electrons
c Ca atom loses 2 electrons
d Al atom loses 3 electrons

7 Study the table, then answer the following questions.



a Which atoms have full shells?
b How do atoms with full shells behave?
c How do metal atoms behave?
d How many electrons will calcium atoms lose to acquire full shells?
e How are carbon atoms likely to behave?
f How many electrons do sulfur atoms need to gain to have full shells?
g Will hydrogen atoms form ions or molecules?
h Summarise the behaviour of non-metal atoms (see page 86 to identify non-metals).
i Which non-metal atoms can form ions?

8 Use the chart above to predict the ions that the following atoms will form.
a H **b** Li **c** Be **d** O **e** F
f Na **g** Mg **h** Al **i** S **j** Cl
k K **l** Ca

9 Name the following complex ions.
a OH^- **b** NO_3^+ **c** CO_3^{2-} **d** HCO_3^-
e SO_4^{2-} **f** NH_4^+

10 Copy and complete the following statements.
a Metal atoms tend to __________ electrons.
b Metal atoms tend to form __________ ions.
c Metal atoms cannot be part of __________.
d Non-metal atoms can __________ or __________ electrons.
e Some non-metal atoms can take electrons from __________ atoms.
f Non-metal atoms can form __________ by sharing electrons.

g Non-metal atoms can form __________ ions by taking electrons.

h Metal atoms can form __________ ions by __________ electrons to non-metal atoms, which become __________ ions by __________ electrons.

11 Read the passage below, then answer the questions.

Bonding in diamond and graphite

Diamonds are extremely hard transparent crystals that are used to cut and grind other materials. Diamond is one form of the element carbon. Another form is graphite, which is the soft black substance found in pencil lead.

Different forms of an element are called **allotropes**. Diamond and graphite are allotropes of carbon. But how are the carbon atoms arranged to give such different properties?

Carbon atoms have four valence electrons in their outer shells. Carbon nuclei are not strong enough to pull electrons off other atoms, but nor are they so weak they lose electrons to other atoms.

So carbon atoms share electrons with other atoms to gain full shells and a stable state. Carbon atoms form strong covalent bonds.

A carbon atom needs to be sharing eight electrons in total with other atoms to gain a full outer shell.

In both diamond and graphite, billions of carbon atoms are bonded in a lattice, but the lattice is made of atoms, not ions.

In diamond, each carbon atom is covalently bonded to four other atoms in a three-dimensional lattice. A diamond is actually a giant molecule, and the network of strong covalent bonds makes it extremely hard.

In graphite, each carbon atom is covalently bonded to three other atoms in sheets made of millions of atoms. The sheets slide over each other, which makes graphite so soft it can be used as a lubricant. The sheets also separate readily.

a Compare the appearance and physical properties of diamond and graphite.

b Are diamond and graphite both elements?

c What are allotropes?

d Why is it that carbon atoms do not lose or gain electrons?

e What do carbon atoms do to gain full outer shells?

f What type of bonds do carbon atoms form? Are they weak or strong bonds?

g Are diamond and graphite molecules? Do they form lattices?

h Explain why diamond is very hard and graphite is very soft.

12 If a formula contains metal atoms, then it must be an ionic compound.

Use the guidelines to write ratios for these ionic compounds.

a $NaCl$ **b** Na_2O **c** MgO **d** $MgCl_2$

e Al_2O_3

Interpreting an ionic formula

- ☐ the formula specifies the ratio of types of ions present in compound, not exact numbers
- ☐ symbols give types of ions present
- ☐ small numbers after ions give the ratio of the different ions; no number means only one
- ☐ brackets are used around complex ions if more than one is present in ratio
- ☐ charges on ions are not shown

Example 1: $\mathbf{ZnCl_2}$ means 1 Zn^{2+}:2 Cl^-

$\mathbf{ZnCl_2}$ has 1 zinc ion to every 2 chloride ions

Example 2: $\mathbf{Ca(NO_3)_2}$ is 1 Ca^{2+}:2 NO_3^-

$\mathbf{Ca(NO_3)_2}$ has 1 calcium ion to every 2 nitrate ions

Write interpretations of these ionic formula.

f $CaCl_2$ **g** K_2O **h** KCl **i** $Mg(OH)_2$

j $CaCO_3$ **k** Na_2SO_4 **l** $Mg(NO_3)_2$ **m** NH_4OH

n $Al(OH)_3$

Unit 15

Metals

Learning outcomes

On completing this unit you should be able to:

- ☐ Describe the common physical properties of metals
- ☐ Relate these properties to bonding between metal atoms
- ☐ State the reaction patterns of metals with oxygen, water and acid
- ☐ Place common metals into a reactivity series
- ☐ Balance the formula of an ionic compound

Physical properties

Metals are very important in everyday life; bike frames and car bodies are made of metal; appliances have metal casings; utensils and cooking pots are made of metal; scissors and nails are made of metal.

Property	**Metals**	**Exceptions**
colour	silvery-grey	copper and gold
state	solid	liquid mercury
melting point	mostly high	mercury
mass	mostly heavy	aluminium
strength	mostly strong	lead and gold
lustre	shiny surfaces	none
flexibility	malleable and ductile	none
conductivity	heat and electricity	none

Metallic and non-metallic substances can be easily distinguished. Metals are strong, dense, shiny solids and can be worked into different shapes. They are good conductors of heat and electricity.

These features are called the **physical properties** of metals as no chemical reactions are involved.

Atomic structure of metals

Physical properties can be explained by considering the structure and **bonding** of metal atoms. Metal atoms are arranged in layers making up a **lattice**. The atoms are tightly packed, which is why metals are heavy.

A few electrons in the outer shell of metal atoms are weakly attracted by the nucleus and are able to wander from atom to atom. As these **free electrons** can travel, metals are good conductors of electricity and heat.

When free electrons move away from an atom, that particular atom momentarily has an overall positive charge. The attraction between positively charged metal atoms and negatively charged free electrons is the 'glue' that holds metal atoms together. This force of attraction between metal atoms is called **metallic bonding**.

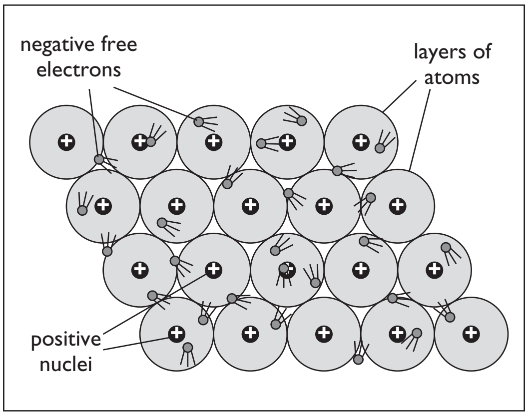


Figure 15.1 Metallic bonding

The strength of the bonding makes most metals solids. Metals have high melting points as much heat energy is needed to overcome the bonds holding atoms in the solid state.

The strength of metallic bonding also makes metals **ductile** (stretchable) and prevents them shattering when hammered. Metals are **malleable** (deformable) because the layers of atoms slide easily over each other.

Elements and alloys

Pure metals are elements – each metal is made up of only one type of atom. There are over 80 different types of metallic elements.

You need to be familiar with the special properties and uses of aluminium (Al), calcium (Ca), copper (Cu), iron (Fe), lithium (Li), magnesium (Mg), lead (Pb), zinc (Zn) and gold (Au).

Most of the metallic substances found in everyday life are actually alloys, which are formed by mixing other elements into the hot molten metal. Steel, brass and 'silver' and 'gold' coins are all alloys.

Alloys are neither elements nor compounds; they are mixtures. **Alloying** gives the metal new properties, e.g. increased hardness or strength.

Chemical properties

Chemical properties relate to how metals react with other chemicals. You need to know the pattern of reactions that metals have with oxygen, water and acids.

Metal atoms have a few loosely held outer electrons that move from atom to atom. These free electrons can be lost altogether when a metal reacts with another chemical. Metal atoms lose electrons to become positive **ions**.

Oxygen and metals

When a substance reacts and bonds with oxygen, this is called **oxidation**. **Combustion** is fast oxidation that releases much heat. **Tarnishing** is the slow oxidation of metals. Some metals combust, others tarnish slowly.

Magnesium ribbon combusts with an intense white flame when heated in oxygen, and a white powder forms.

When metal atoms (e.g. Mg) do react with oxygen molecules (O_2), they lose electrons to become positive metal ions (Mg^{2+}). The oxygen atoms gain the electrons and become negative oxide ions (O^{2-}). Oppositely charged ions (Mg^{2+} and O^{2-}) are attracted to each other and form a metal oxide **compound** (magnesium oxide is the white powder).

The word equation for the reaction pattern is:

Metal + oxygen gas ➔ metal oxide
e.g. **Magnesium + oxygen gas ➔ magnesium oxide**

Water and metals

A few metals react with cold water, more will react with steam, but most do not appear to react.

When calcium (Ca) granules are dropped into water, they fizz and gradually disappear, releasing a gas. The gas pops when ignited, so it is hydrogen gas. When the excess water evaporates, a white solid remains.

When a metal does react with water, water molecules pull electrons off the metal atoms to give oxide ions (O^{2-}) and hydrogen gas (H_2). The metal atoms (e.g. Ca) become metal ions (Ca^{2+}) when they lose electrons. The oxide ions react with other water molecules to give hydroxide ions (OH^-). Oppositely charged metal and hydroxide ions (Ca^{2+} and OH^-) are attracted to each other and form a metal hydroxide compound (calcium hydroxide) when the excess water evaporates.

The word equation for the reaction pattern is:

Metal + water ➔ hydrogen gas + metal hydroxide
e.g. **Calcium + water ➔ hydrogen gas + calcium hydroxide**

Acids and metals

Many metals react with acid to give a new compound. Some react violently, others sedately, a few not at all.

Acids such as hydrochloric (HCl), sulfuric (H_2SO_4) and acetic (CH_3COOH) release hydrogen (H^+) ions when dissolved in water. These ions are the 'acid particles' that react with metal atoms.

For example, when zinc (Zn) granules are placed in hydrochloric acid (HCl), a colourless gas is released as the granules slowly disappear. The gas pops when ignited, indicating that it is hydrogen. When the excess liquid evaporates, a white solid remains.

When a metal reacts with an acid, hydrogen ions (H^+) pull electrons off the metal atoms to become hydrogen gas (H_2). The metal atoms (e.g. Zn) become metal ions (e.g. Zn^{2+}) when they lose electrons. The positive metal ions and the negative ions that made up the other part of the acid (e.g. Cl^-) are attracted to each other, and form a salt (e.g. magnesium chloride) when excess water evaporates. A **salt** is a compound formed when a metal reacts with an acid.

The general word equation is:

Metal + acid ➔ hydrogen gas + salt
e.g. **Zinc + hydrochloric acid ➔ hydrogen gas + zinc chloride**

Reactivity of metals

The reactivity of common metals can be compared and a **reactivity series** established:

Ca > Mg > Al > Zn > Fe > Pb > Cu

The symbol > means more reactive.

(Li is more reactive than Ca, and Au is less reactive than Cu.)

Aluminium does not react as it acquires a thin, resistant oxide coating when first exposed to air.

The reactivity of a metal depends on how tightly its atoms hold on to the free electrons. The atoms of unreactive metals hold on very tightly, but the atoms of reactive metals lose free electrons readily.

Activity 1 Balancing compounds

Compounds are electrically neutral. Positive charges must balance the negative ones.

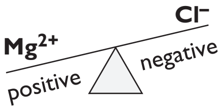
Problem:
Write a balanced formula for magnesium chloride.

Steps:

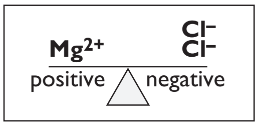
1 Write down the ions: Mg^{2+} Cl^-

2 Draw a see-saw diagram of the ions:

There are 2 positive charges to every 1 negative – unbalanced!



3 Add extra ions till the charges balance:



4 Ratio of ions is: $1Mg^{2+}:2Cl^-$ the formula is: $MgCl_2$

Activity 2

1 Match up the descriptions with terms.

a metals	**A** electrons that can wander from atom to atom
b physical properties	**B** comparison of the reactivity of metals
c bonding	**C** forces of attraction that hold atoms together
d lattice	**D** other elements are mixed into the molten metal
e free electrons	**E** charged atoms
f metallic bonding	**F** able to be stretched out into thin wires
g ductile	**G** strong, shiny solids that are good conductors
h malleable	**H** substance in which different types of atoms are bonded
i alloying	**I** a regular arrangement of atoms in a solid
j chemical properties	**J** properties that do not involve chemical reactions
k ions	**K** the rapid oxidation of a substance
l oxidation	**L** attraction between metal atoms and free electrons
m combustion	**M** a reaction in which oxygen bonds to another substance
n tarnishing	**N** able to be hammered or squashed into a new shape
o compound	**O** compounds formed when an acid reacts with a metal
p acids	**P** the slow oxidation of a metal in air
q salts	**Q** substance that releases H+ ions in water
r reactivity series	**R** properties that relate to how a substance reacts

2 Explain the differences:

- **a** metals and non-metals
- **b** physical and chemical properties
- **c** ductility and malleability
- **d** metal and an alloy
- **e** combustion and tarnishing.

3 Consider common physical properties of metals.

- **a** Most metals are silvery-grey. Which metals are the exceptions?
- **b** What state are most metals at room temperature? What is the exception?
- **c** What temperature would you need to cool mercury to in order to turn it into a solid?
- **d** Which metals are very dense?
- **e** Which metal is the best electrical conductor (least resistance)? Which cheap metal is the best conductor?
- **f** Which metal is the best heat conductor? The poorest?
- **g** Which is the strongest metal? The weakest?
- **h** Which metals would remain shiny in the air even after a long period of time?

4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** Pure metals are rarely used in everyday objects.
- **b** All metals are silvery-coloured solids.
- **c** Physical properties also include the reactivity of the metal.
- **d** The physical properties of metals can be explained by the bonding between metal atoms.
- **e** Metal atoms are held together by metallic bonding.
- **f** Metals can be hammered into new shapes and stretched into thin wires.
- **g** An alloy is a pure metal.
- **h** Metal atoms lose electrons to become negative ions.
- **i** Tarnishing is the slow oxidation of the surface of a metal in air.
- **j** All metals react with water to release hydrogen gas.
- **k** A salt is a compound.
- **l** A reactive metal holds on tightly to its free electrons.

5 Use the data in the table to decide on the best metals to use.

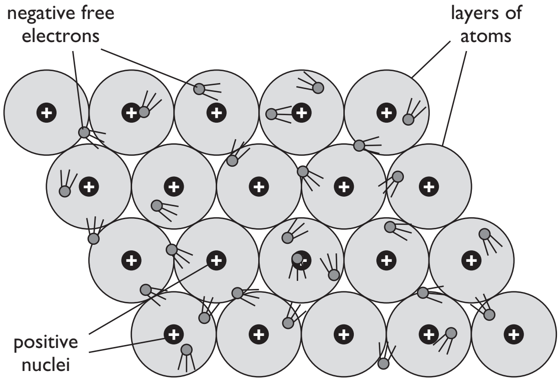
Write down your reasons. Remember that cost comes into it too.

- **a** metal jewellery
- **b** bridge building
- **c** aircraft wings
- **d** electrical wires
- **e** thermometers
- **f** fishing sinkers
- **g** ladders
- **h** car bodies
- **i** cooking pots
- **j** scissors.

Metal	**Al**	**Cu**	**Fe**	**Mg**	**Pb**	**Zn**	**Hg**	**Ag**	**Au**
Colour	silvery	copper	silvery	silvery	silvery	silvery	silvery	silvery	gold
State	solid	solid	solid	solid	solid	solid	liquid	solid	solid
MP (°C)	660	1083	1535	650	327	420	–39	961	1063
Density (g/cm3)	2.70	8.89	7.85	1.74	11.3	7.1	13.6	10.5	19.3
Resistance	2.67	1.72	5.2	4.24	20.6	5.92	95.9	1.63	2.20
Heat conduction	242	383	71	154	36	111	9	414	300
Strength	7.0	11.0	11.0	4.1	1.6	8.0	–	7.7	8.0
Corrosion	resistant	tarnish	rusts	tarnish	tarnish	tarnish	–	resistant	resistant

6 Study the diagram and use it to explain these properties:

- **a** metals are dense
- **b** metals are good electrical conductors
- **c** metals are good heat conductors
- **d** nearly all are solids
- **e** most have high MPs
- **f** metals are ductile
- **g** metals are malleable.



7 Refer to the section on Chemical Properties to answer these questions.

- **a** When metals react, what happens to their free electrons?
- **b** What do metals atoms become in a reaction?
- **c** When a metal reacts with oxygen, what is the product?
- **d** Write a word equation for the pattern of reactions between metals and oxygen gas.
- **e** When a metal reacts with water, what are the final products after excess water has evaporated?
- **f** Write a word equation for the pattern of reactions between metals and water.
- **g** When a metal reacts with an acid, what are the final products after excess water has evaporated?
- **h** Write a word equation for the pattern of reactions between metals and acids.

8 Metals are not equally reactive with oxygen or water or acid.

- **a** Arrange these common metals from the most to the least reactive: Al, Ca, Cu, Fe, Mg, Pb, Zn.
- **b** The only metal elements that are found existing naturally are gold and silver. Are they likely to be reactive or unreactive?

9 Read the passage below, then answer the questions that follow.

Metal alloys

Most of the metallic substances you use in everyday life are likely to be alloys rather than pure metal elements.

An alloy is a mixture of several elements. Usually small amounts of one element or several other elements are mixed into the main metal. Added elements are usually metals, although sometimes non-metal elements such as carbon are used.

The other elements are added in controlled amounts to the molten metal element when it is being smelted.

Alloys have typical metallic properties (shiny, flexible, good conductivity), but they can be harder, stronger or more resistant to corrosion than the original metal. Often an alloy will have a lower melting point than the metal, which will make it easier to work.

One of the earliest alloys to be discovered by humans was bronze, which has some tin mixed into copper to make the copper stronger. Brass is a hard alloy of copper and zinc, which was used for many machine parts during the Industrial Revolution.

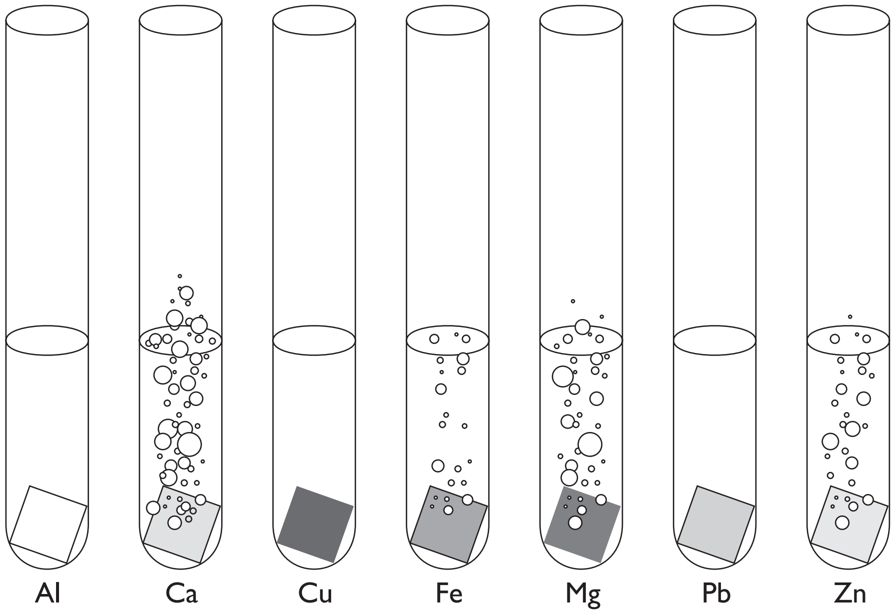
Iron is abundant, but pure iron metal is not very strong and rusts rapidly. Steel, an alloy of iron with small amounts of carbon and manganese, is much stronger and more resistant to corrosion. Stainless steel, which does not rust, contains chromium and nickel.

'Silver' coins are made from an alloy of copper and nickel. 'Gold' coins are made of an alloy of aluminium and copper. 14 carat gold is made of 33% gold and 66% copper!

Chemists can produce 'designer alloys' for very specific purposes, e.g. light, strong, heat resistant alloys for spacecraft and aircraft.

a Are most metallic substances alloys or metal elements?
b What is an alloy?
c How and when is an alloy mixture formed?
d What properties of the metal can be changed by alloying?
e What is bronze and why was it important early in human history?
f What is brass and why was it important?
g Why is steel so much more useful than iron?
h What alloys are used for coins?
i What are 'designer alloys' and why are they important in technology?

10 Clean 1 cm squares of different metals were placed in dilute hydrochloric acid. The reactions are shown below.



a Which metals did not react with the acid?

b Place the seven metals in order from the most reactive to the least.

c Which metal is not in its expected place? Suggest a reason why it might not have reacted as strongly as it should have.

d What is the gas being produced? How would you test for it?

In the test-tubes in which reactions occurred, a powder was left behind after excess liquid evaporated. These powders are called salts. Name the salt left behind in the test-tube which contained:

e calcium **f** iron **g** magnesium **h** zinc

When metals do react with acids, hydrogen gas and a salt are produced. Complete these word equations:

i Calcium + hydrochloric acid ➔

j Iron + hydrochloric acid ➔

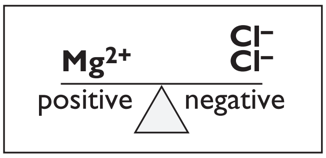
k Magnesium + hydrochloric acid ➔

l Zinc + hydrochloric acid ➔

11 Use Activity 1 on page 101 to write a formula for each compound.

a zinc chloride **b** magnesium oxide **c** calcium chloride

d aluminium oxide **e** copper chloride **f** sodium chloride



Unit 16

Carbon Compound Families

Learning outcomes

On completing this unit you should be able to:

- ☐ Define the alkane, alkene and alcohol families
- ☐ State the formula and draw structural formula of selected compounds
- ☐ Describe trends in the melting and boiling points of alkanes
- ☐ Compare the complete and incomplete combustion of fuels
- ☐ Predict missing data using a line graph

Fuels and energy

A **fuel** is a substance that is burnt to release heat energy.

Most fuels are carbon compounds (e.g. wood, coal, oil, petrol, diesel, CNG and LPG). Fuels in everyday use are hydrocarbons.

Hydrocarbons are **compounds** made of carbon (C) and hydrogen (H) atoms only, bonded together.

The burning of a fuel is called **combustion**, and it requires oxygen gas. The fuel and oxygen gas are the **reactants**. There can be a variety of **products**, such as carbon dioxide gas, water vapour, carbon monoxide gas and soot, depending on the oxygen supply.

Carbon bonding

Carbon is a special element because it forms **molecules** in which each carbon atom can bond with up to four other atoms. This means that large molecules based on long chains of C atoms can exist.

Free carbon atoms have four electrons in their outer shell. To become stable they share electrons with other atoms to gain a full outer shell with eight electrons.

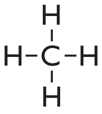
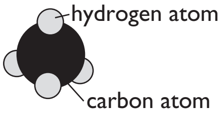
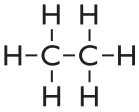
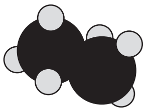
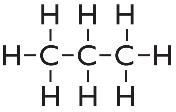
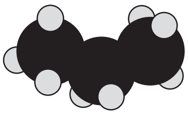
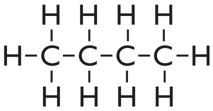
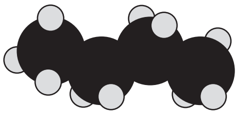
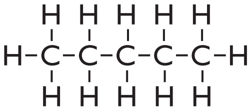
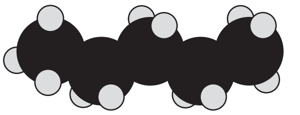
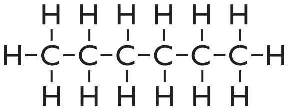
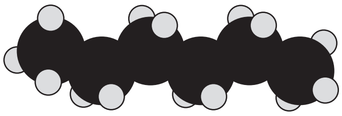
The sharing of a pair of electrons between two atoms (one from each atom) creates a **bond**. Bonds hold atoms together in a molecule.

Each C atom in a compound will form a total of four bonds. Only single bonds are possible with H atoms, but double and triple bonds are possible between two C atoms.

The alkane family

Alkanes are hydrocarbons in which C atoms form single bonds only. So, each C atom is bonded to four other atoms (see structural formulae below).

There are many alkanes, each differing in the number of C atoms.

Name	Formula	Structural formula	3D-model
Methane	CH_4	 $\mathrm{H-\overset{H}{\underset{H}{C}}-H}$	
Ethane	C_2H_6	 $\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$	
Propane	C_3H_8	 $\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$	
Butane	C_4H_{10}	 $\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$	
Pentane	C_5H_{12}	 $\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$	
Hexane	C_5H_{14}	 $\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$	

The general formula of an alkane is:

- ❑ $\mathbf{C_nH_{2n+2}}$
- ❑ **n** is the number of C atoms.

Alkanes are mostly found in **natural gas** and **crude oil**.

Name	Formula	MP (°C)	BP (°C)	State
Methane	CH_4	– 182	– 161	gas
Ethane	C_2H_6	– 183	– 89	gas
Propane	C_3H_8	– 189	– 42	gas
Butane	C_4H_{10}	– 138	0	gas
Pentane	C_5H_{12}	– 130	36	liquid
Hexane	C_6H_{14}	– 95	69	liquid

Alkanes with small molecules are gases, those with larger molecules are liquids and those with very large molecules are solids. All alkanes are insoluble in water.

If an alkane's melting point (MP) is above room temperature (20°C), then the alkane will be a solid. If the alkane's boiling point (BP) is below room temperature, then it will be a gas. If the alkane's MP is below 20°C and its BP above 20°C then it will be a liquid at room temperature.

As alkane molecules get larger, both MP and BP increase. This trend occurs because the attractive forces between molecules increases as the molecules get larger. More heat energy is needed to overcome forces holding particles together in a solid or liquid state.

Chemical properties

Alkanes are unreactive with acids and bases. They do react with oxygen when ignited. If abundant oxygen gas is present, alkanes burn strongly with a blue flame, releasing much heat as **complete combustion** occurs.

- ☐ e.g. **Methane + oxygen ➔ carbon dioxide + water**

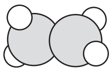
  $\mathbf{CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O}$

If the oxygen supply is limited, then **incomplete combustion** occurs with a yellow flame. Less heat is generated and the smoke contains a mixture of carbon monoxide (CO), carbon dioxide (CO_2), soot (C), unburnt alkanes and water vapour.

Compressed Natural Gas (CNG) is mostly methane gas under pressure. Liquified Petroleum Gas (LPG) is mostly propane and butane gases that have been compressed into a liquid form.

The alkene family

Alkenes are hydrocarbons whose molecules have one double bond somewhere between two of the carbon atoms. The rest of the bonds in the molecules are all single bonds. Each C atom will form four bonds and each H just one.



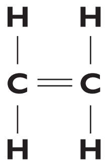
ethene

Alkenes are named in a similar way to alkanes (eth<u>ene</u>, pro<u>pene</u>, but<u>ene</u>), except there is no equivalent to methane.

The general formula for an alkene is $\mathbf{C_nH_{2n}}$. So the formula for ethene, which has two carbons, is C_2H_4.

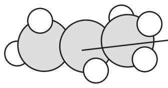
Alkenes show similar trends in MPs and BPs as the alkanes. Smaller alkene molecules (e.g. propene C_3H_6) are gases, larger ones are liquids and the largest ones solids. They are all insoluble in water.

Alkenes are unreactive with acids and bases. They undergo similar combustion reactions with oxygen as the alkanes.



$$\begin{array}{ccc} H & & H \\ | & & | \\ C & = & C \\ | & & | \\ H & & H \end{array}$$

ethene



propene C_3H_6

Alkenes are produced by splitting longer-chain alkanes in a process called **cracking**, which requires heat and a catalyst. Ethene is used to make plastics such as polythene in a process called **polymerisation**.

The alcohol family

Alcohol molecules are basically alkane molecules in which a hydrogen atom has been replaced by an oxygen atom with an attached hydrogen.

The member of the family that you have met is ethanol, which is the alcohol in beer, wine and spirits.

The names for alcohols end in *-ol*. The formula for methanol is CH_3OH and for ethanol is C_2H_5OH. Alcohols are not classed as hydrocarbons as they contain oxygen atoms.

Both alcohols are liquids at room temperature. The BP of methanol is 64°C and of ethanol is 78°C. Both are soluble in water.

Alcohols make good fuels, as much heat is released on burning.

Methanol is manufactured from natural gas. It is highly **toxic** and can cause blindness and death. This alcohol can be used as a fuel after engines have been modified, and is also used as a solvent.

Ethanol is produced by organisms called yeasts. They convert sugars into ethanol and CO_2 gas by **fermentation**. This is a form of anaerobic respiration, which requires the absence of oxygen.

Sugar ➔ ethanol + carbon dioxide

Industrial ethanol is produced by reacting ethene gas with water, at high temperatures over a catalyst:

Ethene + water ➔ ethanol

$C_2H_4 + H_2O \rightarrow C_2H_5OH$

Ethanol is useful as a fuel, and is also used in the manufacture of some perfumes and explosives. Meths is a mixture of ethanol and methanol, plus a purple dye and a chemical that causes vomiting.

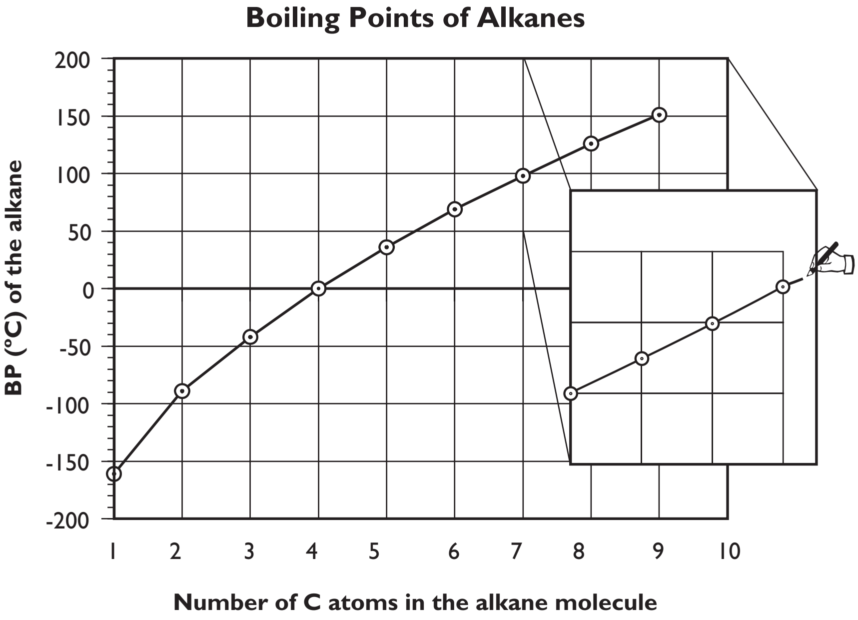
Activity 1 Predicting missing data

Missing data on a line graph can be predicted by extending the graph curve. This is called extrapolation.

Problem:
Predict the boiling point (BP) of an alkane molecule that has 10 carbon atoms.

Steps:

1. Decide whether the graph shows a clear trend: it increases rapidly at first, then rises steadily.
2. Assuming there is a trend, extend the graph curve: continue the line on as a straight line or a smooth curve.
3. Read the predicted value off the graph: the boiling point of an alkane with 10 carbons is predicted to be 180°C.



Activity 2

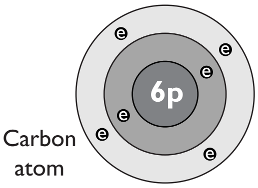
1 Match up the descriptions with the terms.

a fuel	**A** the original substances in a reaction
b hydrocarbon	**B** the conversion of sugars into ethanol and CO_2 by yeast
c compound	**C** hydrocarbon molecules that have single bonds only
d combustion	**D** occurs when a fuel is burnt in an abundant oxygen supply
e reactants	**E** hydrocarbons with one double bond
f products	**F** substance that is burnt to release heat energy
g molecule	**G** group of atoms bonded because they share electrons
h bond	**H** the force of attraction that holds atoms together
i alkanes	**I** poisonous or harmful to living things
j natural gas	**J** a mixture of gases found in Earth's crust
k crude oil	**K** a compound made of carbon and hydrogen atoms only
l complete combustion	**L** a carbon compound with an OH group attached
m incomplete combustion	**M** substance in which non-identical atoms are bonded
n alkenes	**N** the new substances produced in a reaction
o polymerisation	**O** occurs when small molecules are joined in long chains
p alcohol	**P** a mixture of oils found inside Earth's crust
q toxic	**Q** the process of burning a substance
r fermentation	**R** occurs when a fuel is burnt in a limited oxygen supply

2 Use the information in the table below to answer the following questions.

- **a** What is a fuel?
- **b** What three things are required for combustion?
- **c** What are the possible products of combustion?
- **d** Which common fuels come from crude oil?
- **e** Which common fuels come from natural gas?
- **f** Which of the fuels below are stored as gases? liquids? solids?
- **g** Which fuels can be used in vehicle engines?

Fuel	**Components**	**Origins**	**Uses**
CNG	methane	natural gas	vehicle, bunsen
LPG	propane, butane	natural gas	vehicle, stove, lighter
Meths	ethanol, methanol	manufactured	meths burner
Petrol	liquid alkanes	crude oil	vehicle
Diesel	liquid alkanes	crude oil	heavy duty vehicle
Paraffin	solid alkanes	crude oil	candle

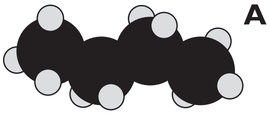


3 Read the section on Carbon Bonding on page 106.
Use the information to explain why more compounds of carbon exist than all the compounds of all the other elements.

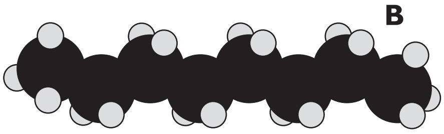
4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** Only fuels release energy when burnt.
- **b** All fuels are solids.
- **c** Hydrocarbons are compounds.
- **d** Combustion always requires oxygen gas.
- **e** Carbon atoms can form bonds with up to four other atoms.
- **f** Bonds hold atoms together in molecules.
- **g** All bonds in alkane molecules are single bonds.
- **h** As the size of alkane molecules increases, the boiling points fall.
- **i** Incomplete combustion occurs when the oxygen supply is limited.
- **j** An alkene molecule has a double bond somewhere between two carbon atoms.
- **k** Alcohols are hydrocarbons.
- **l** Fermentation is carried out by living organisms.

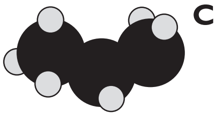
5 Study the diagrams before answering the questions.



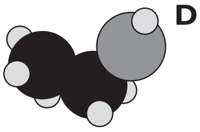
- **a** Is molecule A a hydrocarbon?
- **b** How many carbon atoms does it have?
- **c** A molecular formula gives the number of each type of atom in the molecule. What is the molecular formula of A?
- **d** Alkanes have the general formula $\mathbf{C_nH_{2n+2}}$ and alkenes have the general formula $\mathbf{C_nH_{2n}}$. Is molecule A an alkane or an alkene?
- **e** What is the name of molecule A?
- **f** A structural formula shows what is bonded to what. Make a drawing to show the structural formula of molecule A.



- **g** Is molecule B a hydrocarbon?
- **h** What is its formula?
- **i** Is B an alkane or an alkene?
- **j** Make a drawing to show the structural formula of molecule B.

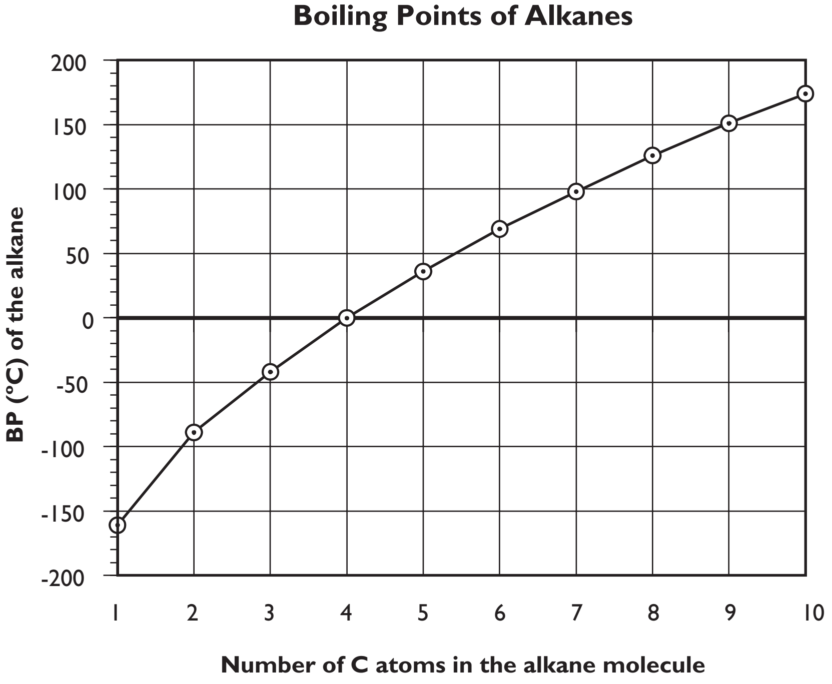


- **k** Is molecule C a hydrocarbon?
- **l** What is the molecular formula of C?
- **m** Is molecule C an alkane or an alkene?
- **n** What is the name of molecule C?
- **o** Make a drawing to show the structural formula of molecule C.



- **p** How do you know that molecule D is not a hydrocarbon?
- **q** What is the molecular formula for molecule D?
- **r** What is the name of this alcohol?

6 Use this graph to answer the questions below it.



a What is the BP of pentane (5 Cs)?

b Which alkane will boil at 0°C?

c Describe the shape of the graph.

d What trend is shown by the data?

e What does the line at 0 (zero) indicate?

f The names of the first ten alkanes in order are *methane, ethane, propane, butane, pentane, hexane, heptane, octane, nonane, decane*. Which will be gases at room temperature (20°C)?

g Which are likely to be liquids at room temperature?

h Can you decide from this graph alone which are solids?

7 Construct a line graph to display the melting points of the first ten alkanes. Place the number of carbon atoms in the alkane along the horizontal axis, and the MP on the vertical axis. Use a scale of –200°C to +50°C for the melting points. Draw a line across at 20°C.

Alkane C	Atoms	MP(°C)
Methane	1	–182
Ethane	2	–183
Propane	3	–189
Butane	4	–138
Pentane	5	–129
Hexane	6	–95
Heptane	7	–91
Octane	8	–57
Nonane	9	–54
Decane	10	–30

a Which alkane has the lowest MP?

b Which alkane has the highest MP?

c Describe the shape of the curve.

d What trend is shown by the data?

e Will any of these alkanes be solid at room temperature (20°C)?

f With alkanes that are not solids, what additional information would you need to be able to predict whether they are liquids or gases?

8 Read the passage below, then answer the questions that follow.

Cattle and global warming!

Methane gas is released from marshes, swamps, paddy fields and flooded areas.

Methane produced in the guts of grazing animals and termites is also released into the atmosphere.

In all of these situations, the gas is produced by bacteria that thrive in the absence of oxygen gas.

In places where oxygen is absent, these bacteria convert dead plant and animal material (as well as animal wastes) into carbon dioxide and methane gases.

The bacteria are part of a group of organisms called decomposers, which cause the breakdown of organic matter.

Methane is a colourless, odourless gas. The unpleasant smell comes from gases that are sulfur compounds.

Methane is lighter than air and rises in the atmosphere. It is one of the greenhouse gases that affect global warming. The increasing volume of methane gas (because of increased rice cultivation and growing cattle numbers) is of concern to scientists.

Methane gas is also produced at sewage treatment plants when bacteria attack the sludge in special holding tanks in which oxygen gas is absent. The gas, which is called biogas, can be stored and later used as a fuel.

Biogas is a mixture of methane and carbon dioxide. It can be burnt to generate electricity to supply the sewage plant, or it can be used as a fuel to run vehicles that have modified engines.

a What type of land areas is methane gas released from?

b What animals also produce significant amounts of methane?

c What conditions do methane-producing bacteria require?

d What are decomposers?

e What two gases released by bacteria found in the guts of cattle are considered to be greenhouse gases?

f How is biogas produced in sewage treatment plants?

g How can biogas be used?

h When biogas is burnt, what products will be formed?

9 The fuel for the bunsen burner shown is CNG. In the top photo the air hole is open, and the gas burns with a blue flame (which is why you can't see it very well).

- **a** What is the main gas in CNG?
- **b** What gas, required for combustion, enters through the air hole?
- **c** Is the reaction complete or incomplete combustion?
- **d** What will be the two main products from the combustion of CNG in photo A?
- **e** Write a word equation for this reaction.
- **f** Complete a formula equation for the reaction shown in the above photo.

In the bottom photo the air hole is nearly closed, which limits the supply of oxygen.

- **g** What sign is there that incomplete combustion is occurring?
- **h** Write a word equation to summarise the reactants and products involved in incomplete combustion.
- **i** What poisonous gas is produced in incomplete combustion?
- **j** If a beaker was heated by this flame, the outside would turn black. Why?
- **k** Give two reasons why it is better to have the air hole open when heating with a bunsen.

10 Micro-organisms called yeast are used in baking bread as well as in the fermentation of beer.

- **a** What raw material does yeast require?
- **b** What are the two products of fermentation?
- **c** What does fermentation do to the bread dough?
- **d** What happens to the alcohol formed as the dough rises?
- **e** What does the gas produced in fermentation do to the beer?
- **f** Which alcohol is found in beer?

Unit 17

Energy And Change

Learning outcomes

On completing this unit you should be able to:

- ❑ Provide a scientific definition of the concept of energy
- ❑ Define energy types and classify them as either active or potential
- ❑ Identify energy transformations occurring and give examples
- ❑ State and apply the law of Conservation of Energy
- ❑ Calculate the energy efficiency of a device or object

What is energy?

Energy is an extremely useful scientific concept that can be used to explain many different events and processes in all areas of Science.

Energy is not a substance or an object, although objects can possess energy. In Science, the word **energy** basically means having the capacity to do something. A more formal definition is that energy is the capacity to do work.

Heat, electrical, chemical, elastic, kinetic and gravitational energy are covered below.

Active energy involves energy being used to do something that can be observed or measured, e.g. solar energy from the sun or sound energy from a vibrating speaker. **Potential energy** involves energy being stored in some way. Forms of potential energy include chemical, elastic and gravitational.

Energy, **E**, is a physical quantity that is measured in units called **joules** (symbol J). One joule is defined as the amount of energy needed to move an object one metre using a force of just one newton.

A joule is a very small amount of energy, so **kilojoules** (symbol kJ) are usually used instead: **1 kilojoule = 1000 joules 1 kJ = 1000 J**

Heat energy

Heat energy flows from hotter objects to cooler objects. Heat energy is related to the movement of atoms making up an object. If more heat is supplied, these particles move more rapidly.

Supplying heat energy to an object usually causes an increase in its temperature.

The mass of an object is also important: a red-hot metal bar will possess much more heat energy than a red-hot needle!

So, the amount of heat energy an object has is related to temperature and mass of the object.

Electrical energy

Electrical energy is the energy associated with charged particles moving in a current. The particles involved are usually electrons.

The larger the current, the more electrical energy is transported in a circuit.

The greater the voltage supply the more electrical energy is transported. The mains supply at 240 V will provide a lot more electrical energy than a 1.5 V battery!

So, the amount of electrical energy supplied in a circuit depends on the size of the current and of the voltage supply.

Chemical energy

Chemical energy is a form of potential energy that is stored in the chemical bonds that hold the atoms of a substance together.

This energy can be released in chemical reactions. The chemical energy is turned into heat or light or sound energy.

Substances such as food, fuels and explosives have chemical potential energy.

The amount of stored chemical energy in a fuel or food is found by measuring the heat released when the chemical is combusted.

Elastic energy

Elastic energy is a form of potential energy associated with stretched or squashed objects that are able to regain their shape when released. These objects are called elastic objects.

The amount of energy stored in a stretched rubber band depends on how much it is stretched.

The thickness of the rubber band also affects the amount of stored energy. A thick stretched rubber band will have much more elastic energy stored in it than a thin band stretched to the same length.

So, the amount of elastic energy stored in an object depends on how much it is stretched (or squashed) and the nature of the elastic object.

Energy changes

An **energy transfer** occurs when energy is passed from one object to another. The type of energy involved may remain the same, e.g. when you sit by a heater, heat energy is transferred from the heater to make you hotter.

An **energy transformation** occurs when energy is changed from one form to another, e.g. in an electric fan electrical energy is transformed into kinetic energy of the blades and heat energy due to **friction** in the motor.

When energy is transferred or transformed, the total amount of energy before and after remains exactly the same. This principle is the basis of the Law of Conservation of Energy.

Law of Conservation of Energy:

Energy cannot be created or destroyed, but can only be transformed from one form to another.

This law means that energy must come from somewhere – there must be a source of energy, e.g. food for humans, petrol for cars and sunlight for plants.

When energy is transformed from one type into another, usually there is less **useful energy** available after the transformation. This does not mean that energy is lost or destroyed, rather some of the energy will have been changed into a form that is no longer usable (usually heat energy produced by friction). For example, only about 30% of the chemical energy in petrol is transformed into kinetic energy of the car; the other 70% is changed into heat, which is no longer useful energy. Energy that is no longer useful after a transformation is called **waste energy**.

The rate at which energy is transferred is referred to as **power**.

Kinetic energy

Kinetic energy is the energy associated with a moving object.

A heavier object travelling at the same speed as a lighter object has more kinetic energy. Getting hit by a golf ball is a much more painful experience than being hit by a table-tennis ball! If the mass is doubled, then the kinetic energy is also doubled.

If the speed of an object is increased, then its kinetic energy increases dramatically. A cyclist travelling at 50 km hr^{-1} has four times as much kinetic energy as when travelling at 25 km hr^{-1}. If the speed doubles, then kinetic energy quadruples!

So, the amount of kinetic energy a moving object has depends on two factors: its mass and, more critically, its speed.

Gravitational energy

Gravitational energy is a form of potential energy that is associated with the height of an object above Earth's surface.

As an object is lifted it gains stored gravitational energy. This energy is converted into kinetic energy when the object falls.

The higher an object is lifted, the more gravitational potential energy it gains. A brick lifted 20 m has twice as much potential energy as when it is lifted to only 10 m.

Heavier objects have more gravitational energy than lighter objects lifted to the same height. A 20 kg rock lifted 10 m will have twice as much gravitational energy as a 10 kg rock lifted 10 m.

Gravitational energy depends on the height an object is lifted and its mass.

Activity 1 Calculating efficiency

The Law of Conservation of Energy is used when calculating how efficient an object or device is at converting energy from one type to another.

- ❑ In a transformation, the amount of energy supplied is called the **energy input**.
- ❑ The energy after the transformation is referred to as the **energy output**.
- ❑ According to the Energy law: **Energy output = energy input**
- ❑ The energy output will consist of useful energy and waste energy:

  Energy output = useful energy + waste energy
- ❑ The **energy efficiency** of an object or device is calculated by:

$$\textbf{Efficiency (\%)} = \frac{\textbf{useful energy x 100}}{\textbf{energy input}}$$

Problem:

Cold water was heated in an electric jug until it boiled. The jug received 240 kJ of electrical energy and the water gained 190 kJ of heat energy. What is the energy efficiency of the jug?

Steps:

1 Identify the energy input and useful energy: energy input = 240 kJ
useful energy = 190 kJ

2 Make sure both figures are in the same units: both are in kJ

3 Substitute the values into the formula:

$$\text{Efficiency (\%)} = \frac{190 \text{ x } 100}{240}$$

4 Use your calculator: 190 x 100 ÷ 240 = 79.166666

5 Round off the answer: Efficiency of jug = 79%

Activity 2

1 Match up definitions with terms.

a energy	**A** energy carried by charged particles travelling in a current
b potential energy	**B** equal to 1000 joules
c joule	**C** occurs when the type of energy passed on is changed
d kilojoule	**D** energy associated with moving objects
e heat energy	**E** defined as the capacity to do work
f electrical energy	**F** energy that is able to be utilised in some way
g chemical energy	**G** energy stored in the bonds that hold atoms together
h elastic energy	**H** the energy supplied in an energy transformation
i kinetic energy	**I** force between moving surfaces which produces heat
j gravitational energy	**J** energy that is stored in some way
k energy transfer	**K** the energy produced in an energy transformation
l energy transformation	**L** when the type of energy passed on remains the same
m friction	**M** the scientific unit for energy
n useful energy	**N** the % of input energy which becomes useful energy
o waste energy	**O** energy that travels from a hotter to a colder object
p energy input	**P** energy that is stored in stretched or squashed objects
q energy output	**Q** output that cannot be used
r energy efficiency	**R** energy stored in objects held above the ground

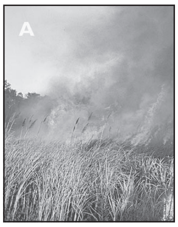
2 Explain the difference between:

- **a** active and potential energy
- **b** energy transfer and transformation
- **c** energy input and output
- **d** useful energy and waste energy.

3 Classify each of the following types of energy as either active or potential forms.

a kinetic
b heat
c electrical
d sound
e light
f elastic
g chemical
h gravitational

4 For each of the energy transformations shown below identify the original type of energy involved (energy source) and the types of energy it is transformed into. There may be several new types of energy involved.


A


B


C

5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** Energy is a substance.
- **b** Having energy means having the capacity to do work.
- **c** With active forms of energy the effects can be observed or measured.
- **d** Potential energy can come in a variety of forms, e.g. chemical and elastic energy.
- **e** A joule is the amount of energy needed when a force of one newton moves an object one metre.
- **f** Heat energy depends on the temperature of the object only.
- **g** Electrical energy travels along conductors.
- **h** Chemical energy is held in the bonds between atoms.
- **i** When an object is lifted it gains gravitational energy; when it falls it gains kinetic energy.
- **j** In many energy transformations, some of the useful energy is destroyed.
- **k** Output energy is always equal to input energy.

6 For each of the following examples identify which type of energy is involved, then state the factors which can affect the amount of energy possessed.

Situation	Energy Type	Factors Involved
can of petrol	chemical	energy in bonds
diver on platform		
red-hot horseshoe		
stretched catapult		
speeding skater		
shock from mains		

Situations

bungee jumper leaping
bungee jumper slowing
a battery charging
firing an arrow
glowing stove element
going up in a lift
sky rocket taking off
solar panel in sunlight
steam engine in action

7 Select the best example in the list opposite to match each energy transformation listed below.

- **a** light into electrical
- **b** kinetic into elastic
- **c** chemical into kinetic
- **d** elastic into movement
- **e** gravitational into kinetic
- **f** heat into kinetic
- **g** kinetic into gravitational
- **h** electrical into heat
- **i** electrical into chemical.

8 Use these two formulae to complete the table that follows.

$$\textit{Energy Output} = \textit{Energy Input}$$
$$\textit{Energy Output} = \textit{Useful Energy} + \textit{Waste Energy}$$

Appliance	Energy (joules per second)			
	Input	Useful	Waste	Output
toaster	1500	300	1200	1500
heater	2400		200	
radio		45		60
jug	2000		600	
lamp		10		100
shaver	200		70	

9 Use the results from the table above and the formula below to find the energy efficiency of each appliance to the nearest %.

$$\textit{Energy Efficiency} = \frac{\textit{Useful Energy x 100}}{\textit{Energy Input}}$$

Appliance	Useful Energy (J/s)	Energy Input (J/s)	Efficiency (%)
toaster			
heater			
radio			
jug			
lamp			
shaver			

a List the appliances from the most to the least energy efficient.

b What is the most common form of waste energy involved?

c Why are useful and input energy both given in joules per second?

10 Read the passage below, then answer the questions that follow.

Efficiency and friction

Many appliances convert electricity into movement, e.g. electric fan, electric shaver, kitchen blender and an electric drill.

Although the desired type of energy in each case is kinetic energy, other types of energy are also produced, such as sound.

After use, all of these appliances will feel hot, so some of the electrical energy must have been converted into heat.

Devices in which parts move produce heat because of friction. Friction is the force that occurs between surfaces that are moving against each other.

Inside all motors there is a shaft that is made to rotate through the interaction of electrical and magnetic force fields. This shaft is supported by bearings, and as the shaft spins on the bearings friction occurs.

Friction is actually due to temporary attraction between the particles that make up the two surfaces that are moving against each other.

When friction occurs between surfaces, the moving parts will slow down slightly and some of their kinetic energy is converted into heat energy as the surfaces drag past each other.

The more friction there is, the more heat will be produced and the less useful kinetic energy the appliance will have, so its efficiency will decrease.

Different methods are used to reduce friction in bearings. Usually the two metal surfaces are made smooth to reduce drag. Lubricants such as grease and oil may be used to reduce friction. Ball-bearings may be used to roll surfaces past each other rather than sliding them over each other.

a What is the useful energy transformation that occurs inside an electric motor?

b What other energy forms are produced by an electric motor?

c Identify the input and output energy types of an electric drill.

d Why is the heat energy produced by a drill classified as waste energy?

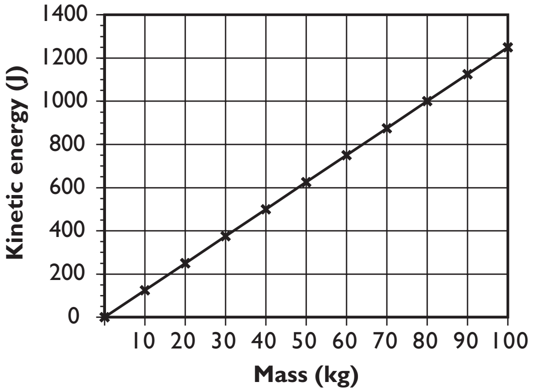
e How is heat energy produced by a drill?

f What are three ways of reducing friction between moving parts?

g Why is it impossible to have a motor that is 100% efficient?

h Why would a hair dryer be more energy efficient than an electric fan?

11 This graph shows the kinetic energy of a trolley when its load is increased. Each time the load is increased, the trolley is pushed at a speed of 5 m s^{-1}.



a If the empty trolley has a mass of 10 kg, how much is the load increased each time?

b What is the kinetic energy of the trolley when its mass is 50 kg and when it is 100 kg?

c How much does kinetic energy increase by when mass doubles?

d What is the relationship between kinetic energy and mass?

12 This graph shows the kinetic energy of a cyclist as speed increases.

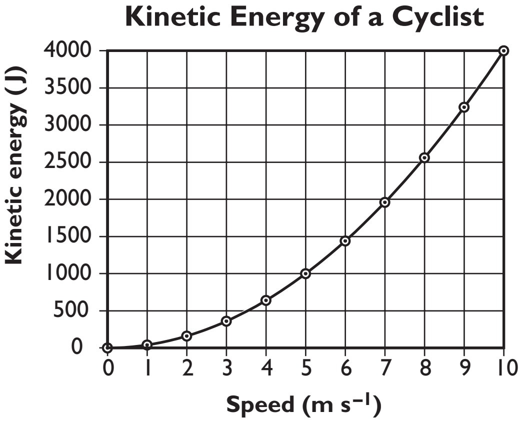
a How does the cyclist's speed increase?

b How does the cyclist's kinetic energy increase?

c What is the cyclist's kinetic energy at 4 m s^{-1} and 8 m s^{-1}?

d What happens to the cyclist's kinetic energy as speed doubles?

e What is the relationship between kinetic energy and speed?



Unit 18

Current, Circuits And Components

Learning outcomes

On completing this unit you should be able to:

- ☐ Describe electrical current and list the requirements of a circuit
- ☐ Distinguish between conductors, insulators and resistors
- ☐ Identify series and parallel circuits and describe some of their properties
- ☐ Recognise different electrical components and state their functions
- ☐ Draw and interpret simple circuit diagrams

Current electricity

Electricity is a very convenient form of energy because it travels rapidly along wires and can be transformed easily into other forms.

At this level, you will be focusing on **current electricity**. A current involves a flow of charged particles. Remember, there are two types of **electrical charge** – positive and negative – and like charges repel each other but unlike charges are attracted to each other.

The particles that flow in electrical currents are usually electrons, which are negatively charged. **Electrons** are the extremely small particles that fly around the nucleus of atoms. In metals, the nuclei of the atoms do not attract the outer electrons very strongly, so these electrons are free to move from atom to atom. These *free electrons* are the charged particles that flow in most electrical currents.

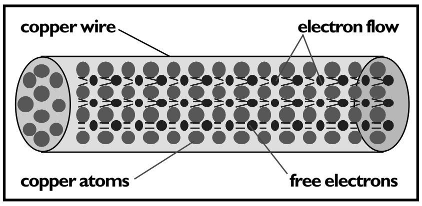


Figure 18.1 Electrical conductor

A substance such as copper, which has free electrons, is called an **electrical conductor**. A conductor allows a current to flow through it. A substance such as plastic, which does not have free electrons, cannot conduct current. So it is called an **electrical insulator**.

Some objects only allow a limited amount of current to flow through them and much of the electrical energy is converted into heat. These substances are known as **resistors** as they oppose the flow of current.

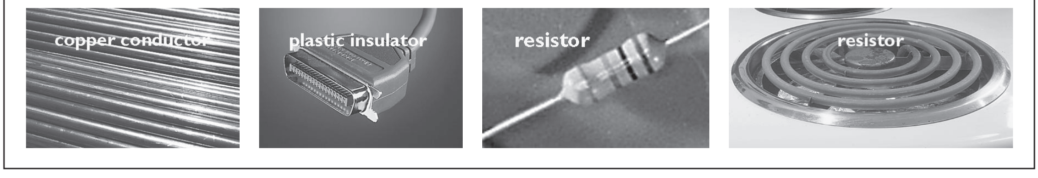


Figure 18.2 Conductors, insulators and resistors

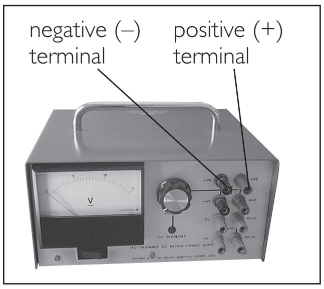


Figure 18.3 Power pack

At this level, you will only be concerned with current that flows in one direction – **direct current** (or DC for short). A battery and a power pack both provide direct current. Devices which produce direct current will have a positive (+) terminal and a negative (–) **terminal**.

To make free electrons move through a conductor, an electrical force field must be present. A battery or power pack creates the **electrical force field**. The negatively charged free electrons found in an electrical force field will be pushed towards the positive terminal. This movement of electrons causes the current.

Electrical circuits

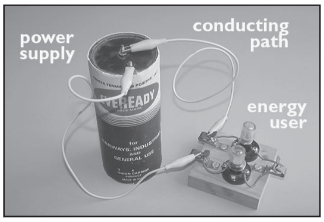


Figure 18.4 Electrical circuit

For a current to flow a **circuit** is required. A simple circuit will have at least three types of components:

- ❑ a power supply, which produces the force to drive the current (e.g. a battery or power pack)
- ❑ some conducting pathways (e.g. copper wires)
- ❑ a device that transforms the electrical energy such as a bulb, speaker, motor or heater.

In a DC circuit electrons flow from the negative terminal of the power supply along a wire, through the device, then back along another wire to the positive terminal. A complete conducting pathway is needed for a current to flow around a circuit.

Figure 18.5 Single branch series

As the current moves through a device, the electrical energy is converted into heat, light, sound or kinetic energy.

The amount of current flowing back into the power supply is the same as the amount of current leaving the power supply. Electrons may lose energy as they travel around a circuit – but the electrons are not lost!

Series and parallel circuits

Figure 18.6 Two branches series

Parts of a circuit or components can be arranged in two distinct ways – in series or in parallel.

If the components are all arranged in a single branch so that the current flows through each component in turn, then the circuit is called a **series circuit**. In a series circuit the current is the same at all points around the circuit. If one component in a series circuit fails, then no current will flow in the circuit.

If the components are arranged in separate branches so that the current travels through several different branches, then the circuit is called a **parallel circuit**. In a parallel circuit, the current can vary in the different branches. If one component in a parallel circuit fails, then other components in different branches can still work.

More complex circuits will have some components in series with each other, and other components connected in parallel to each other.

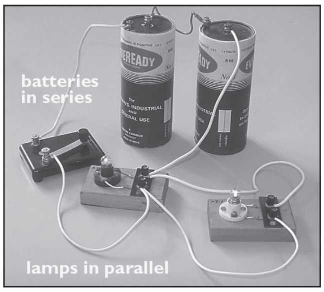


Figure 18.7 Batteries in series

Circuit components

Wires allow current to flow through other components in a circuit. Switches are used to turn the current on or off.

Components that supply electrical energy to a circuit include **solar cells**, power packs and chemical cells. The everyday term for a **chemical cell** is a battery. A penlight battery is a single cell; a car battery has six cells. These components create the electrical force field that drives the current around.

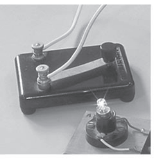
Lamps are components that convert electrical energy into light and heat.

Resistors are used to control the amount of current that flows through a circuit or part of a circuit.

Rheostats are resistors whose resistance can be varied. The greater the resistance, the less current that flows in a circuit.

A **diode** allows current to flow one way only as shown by its symbol's arrow.

An **ammeter** is used to measure the size of a current. A **voltmeter** is used to measure the amount of electrical energy gained or lost by the current. DC meters have a red (+) positive terminal and a black (–) negative one.

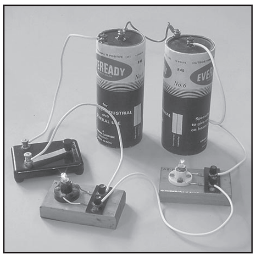


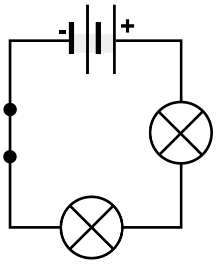
Activity 1 Drawing circuit diagrams

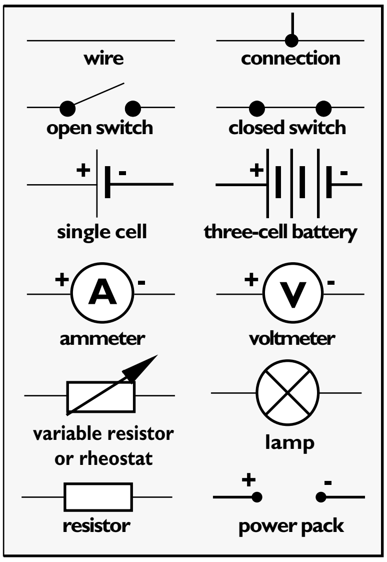
A circuit can be drawn as a **circuit diagram**. Each type of component has a special symbol and the branches of the circuit are drawn as connected rectangles.

Drawing a circuit:

1. Decide whether the circuit has components in series or parallel.
2. If all of the components are in series, draw a single rectangle for the circuit.
3. If the circuit has components in parallel, draw connected rectangles, one for each branch.
4. Identify each component in the circuit and draw its symbol in the appropriate location on the diagram.
5. Ensure symbols are placed in the correct order.
6. Make sure lines that represent wires are straight and connect up with components – no gaps.
7. Check positive and negative terminals of power supply and meters are shown the right way round.







Activity 2

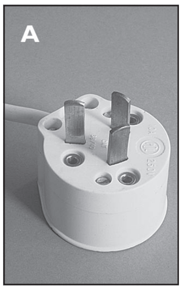
1 Match up descriptions with terms.

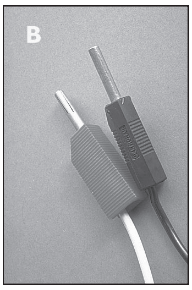
a electricity	**A** current that flows in one direction only
b current electricity	**B** a complete conducting pathway
c electrical charge	**C** allows a current to flow through it
d electrons	**D** an object whose resistance can be varied
e electrical conductor	**E** connection point on a component
f electrical insulator	**F** a circuit where components are in different loops
g resistor	**G** either positive or negative
h direct current (DC)	**H** object that transforms chemical energy into electricity
i terminal	**I** a form of energy associated with charged particles
j electrical force field	**J** object that transforms light energy into electricity
k circuit	**K** object that opposes the flow of current
l series circuit	**L** an instrument that measures the size of a current
m parallel circuit	**M** a flow of charged particles through a conductor
n solar cell	**N** measures electrical energy lost or gained by the current
o chemical cell	**O** a circuit where all components are in a single loop
p rheostat	**P** very small negative particles flying around the nucleus
q ammeter	**Q** provides the force to drive the current around a circuit
r voltmeter	**R** does not allow a current to flow through it

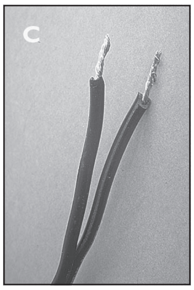
2 Explain the difference between:

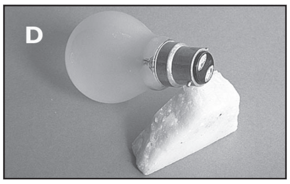
- **a** a conductor and an insulator
- **b** a solar cell and a chemical cell
- **c** series and parallel circuits
- **d** an ammeter and a voltmeter.

3 For each of the following electrical objects, identify the part that acts as a conductor and the part that is designed to act as an insulator.





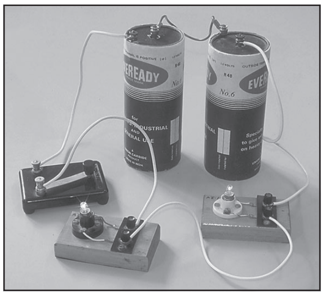




4 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

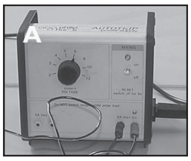
- **a** Electricity is a form of energy that can travel rapidly.
- **b** An electrical current involves a flow of charged particles.
- **c** Atoms are the particles that are moving in most electrical currents.
- **d** An electrical insulator will have many free electrons.
- **e** Resistors are substances that limit the amount of current flowing.
- **f** Direct current means that electrons are travelling in one direction only.
- **g** An electrical force field is needed to drive electrons around a circuit.
- **h** Electrons travel from the positive terminal of a battery around to the negative terminal.
- **i** A current needs a complete conducting pathway.
- **j** If two components are in separate branches, they are said to be in series.
- **k** In a series circuit, the current is the same all the way around.

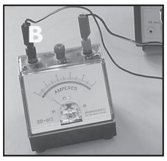
5 Study the circuit to the right.

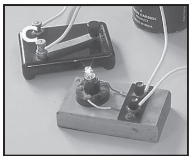


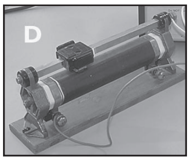
- **a** What types of components are in this circuit?
- **b** Which component produces electricity?
- **c** Which component conducts electricity?
- **d** Which component transforms electricity?
- **e** Is the circuit a complete conducting loop? Why?

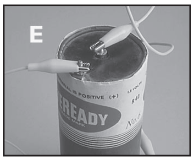
6 Identify each of the electrical components shown below and state its function in a circuit.

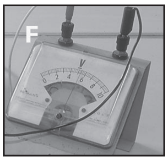


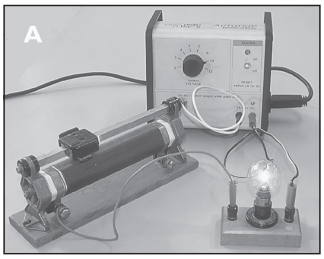












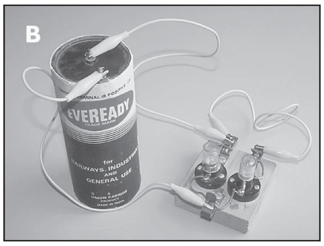
7 Study each circuit in turn and then answer the questions beside them.

a What is the function of the rheostat shown in circuit A?

b Are the rheostat and lamp connected in series or parallel?

c How do you know that circuit A is a complete pathway?

d Draw a circuit diagram for A.

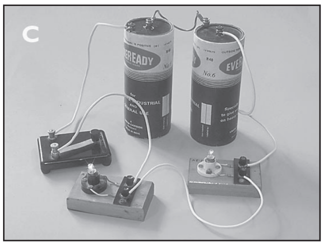


e What is the function of the cell shown in circuit B?

f Are the bulbs in series?

g If the bulbs are equally bright, what can be said about the current going through each?

h Draw a circuit diagram for B.

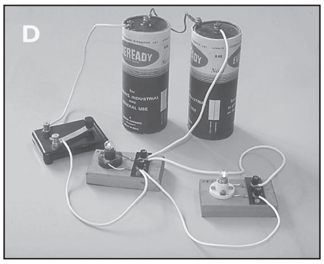


i What is the function of the switch shown in circuit C?

j Are the two cells in series or parallel? What about the bulbs?

k What would happen if one bulb failed in circuit C?

l Draw a circuit diagram for C.



m How are the two bulbs connected in circuit D?

n How are the cells connected?

o If one bulb failed, what would happen to the other?

p Draw a circuit diagram for D.

8 Read the passage below, then answer the questions that follow.

Natural electricity

Lightning is actually high energy electrical currents travelling through the air. Normally, air is a poor conductor because there are no free electrons to allow a current to flow.

In thunderstorms, electrical charges in clouds become separated. Usually the tops of clouds become positively charged, while the bottoms acquire a huge surplus of negative charge.

Scientists think this separation of charged particles is caused by convection air currents inside the clouds.

As the charge builds up on the bottoms of clouds, a huge potential energy difference is created between the negative underside of the cloud and the ground below, which is positively charged.

This electrical potential difference creates a force field between the clouds and the ground, which is strong enough to turn air molecules into ions and release free electrons.

Initially, an invisible 'leader' lightning stroke shoots downwards in zig-zag steps ionising air molecules and releasing free electrons, which turn the air into a conducting pathway. As the leader stroke nears the ground, another invisible leader leaps up from the ground.

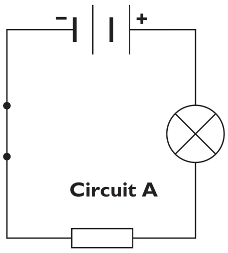
When the two leaders meet, the visible lightning strike occurs. It moves rapidly from the ground along the zig-zag ionised pathway back to the clouds. This happens so rapidly that we do not observe the direction in which lightning travels.

Lightning rods are used to protect buildings. A metal rod on the highest point of the building is connected by a conductor to a metal stake in the ground. Lightning is attracted to the rod and the electricity passes harmlessly into the ground.

- **a** Why is lightning a form of electricity?
- **b** Why is air normally a poor conductor?
- **c** Where are charges concentrated in a thundercloud?
- **d** What causes the separation of charge in a thundercloud?
- **e** Why is an electrical force field created between the cloud bottoms and the earth?
- **f** What does this extremely powerful electrical force field do to air molecules?
- **g** What makes air become a conductor?
- **h** Why are tall objects more likely to receive lightning strikes?
- **i** How do lightning rods protect houses?

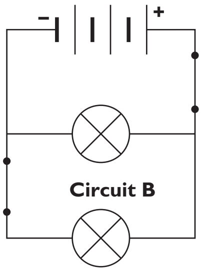
9 Study the circuit diagrams opposite, then answer the questions beside each.

- **a** Is circuit A a series or parallel circuit?
- **b** What is the function of the resistor in circuit A?
- **c** If the switch in circuit A is turned to the off position, what will happen to the bulb?



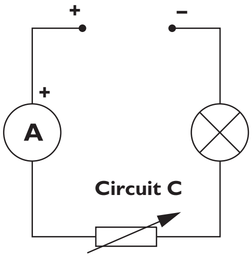
Circuit A

- **d** How many cells are there in circuit B?
- **e** How are the cells connected?
- **f** How are the bulbs connected in circuit B?
- **g** What will happen to the two bulbs in circuit B if just the top switch is turned to the off position?
- **h** What will happen to the bulbs in circuit B if just the bottom switch is turned off?



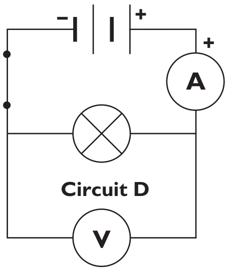
Circuit B

- **i** What component provides electrical energy in circuit C?
- **j** Are components in series or parallel?
- **k** What will happen to the current flowing in circuit C if the resistance of the rheostat is increased?
- **l** What will happen to the brightness of the bulb if the resistance is decreased?



Circuit C

- **m** In circuit D, is the ammeter connected in series or parallel with the bulb?
- **n** Is the voltmeter connected in series or parallel with the bulb?
- **o** Which terminal of the battery do the positive terminals of the meters lead to?



Circuit D

Unit 19

Current And Voltage

Learning outcomes

On completing this unit you should be able to:

- ☐ Define current and relate it to electrical charge
- ☐ Describe what happens to the current in series and parallel circuits
- ☐ Define voltage gain or loss and relate it to potential energy
- ☐ Describe what happens to voltage in series and parallel circuits
- ☐ Use electrical meters effectively and safely

Measuring the current

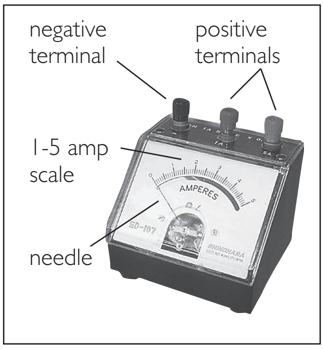


Figure 19.1 Analogue ammeter

Current is a flow of electrical charge. The charge is carried by **electrons** moving along **conductors**.

Charge is measured in units called **coulombs**. A huge number of electrons are needed to give a charge of just one coulomb – 6 250 000 000 000 000 000 in fact!

Current can be defined as the number of coulombs of charge passing per second. Current has the symbol **I** and the unit is the **ampere** or amp (A). A current of one ampere is equal to one coulomb of charge passing per second.

To measure the current an **ammeter** is used. **Analogue ammeters** have a needle that indicates the reading on a scale. **Digital multimeters** have a built-in ammeter and give the current in digits.

Current in series and parallel circuits

In a circuit the number of electrons returning to the power supply per second is the same as the number leaving. Electrons are never lost from a current.

The current in a **series circuit** is the same all the way around the circuit.

In a parallel circuit, as electrons in the current reach a junction some electrons go along one branch and some along the other. So the current from the power supply is shared out amongst the branches.

The currents in branches of a **parallel circuit** add up to equal the current from the power supply.

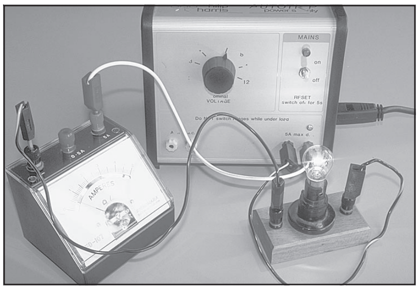
The size of the current in different branches depends on the **resistance** of lamps and resistors in that branch. If branches offer equal resistance, then each branch receives an equal share of the current. If the resistance of branches differ, then the branch with the least resistance receives the biggest share of the current.

Activity 1 Using an ammeter

To measure the current, an ammeter is connected directly into the circuit at the point of interest. It is connected in series with other components. A meter that can measure direct current will have a red positive **terminal** and a black negative one. The connection from the red meter terminal must lead towards the positive terminal of the power supply.

Steps:

1. Set up the circuit. Make sure it works, then switch off.
2. If you are using a digital multimeter, turn the dial to the 10 amp DC setting. If an analogue meter has several red terminals, use the one with the highest range.
3. Identify the wire in which you want to measure the current. Disconnect the end of that wire that leads towards the positive power supply terminal.
4. Connect the end of that wire with the red terminal of the meter, then connect the black terminal with the disconnected component.
5. Check that the connection from the red meter terminal leads towards the positive power supply terminal.
6. Turn on the circuit. If the meter needle flicks backwards, quickly turn off the circuit then swap connections. A digital meter gives a negative reading if connected wrongly.
7. Take the current reading in amps off the meter scale or display.



Steps

1. Set up/turn off
2. Select scale
3. Find +ve end of wire
4. Insert meter in series
5. Check +ve to +ve
6. Test meter
7. Take reading

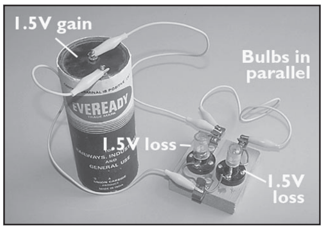
Voltage gain or loss

The power supply in a circuit creates an electrical force field that drives electrons around the circuit. The power supply also provides these electrons with potential energy. The potential energy acquired by the current as it passes through a power pack or battery is called the **voltage gain** or supply.

As the current passes through various components (e.g. lamps), its potential energy is transformed into other forms of energy (e.g. light and heat). This reduction in potential energy as the current passes through components is called **voltage loss**.

Voltage, symbol **V**, can be defined as the energy gained or lost by electrons in the current. The unit for voltage is the **volt** (symbol V). One volt is equal to one joule of energy gained or lost by each coulomb of charge.

To measure the voltage supply, or the voltage loss as the current passes through components in a circuit, a **voltmeter** is used. Either an analogue voltmeter or a digital multimeter with a built-in voltmeter is suitable.



Voltage in series and parallel circuits

In a circuit with a single component, the voltage lost by the current to the component equals the voltage gained by the current from the power supply.

If cells are connected in series, then the total voltage gained by the current is the sum of the voltages supplied by each cell.

If several components such as lamps are connected in series, then each component causes the current to lose a share of the voltage supply.

The voltage lost by the current as it passes through each component adds up to the total voltage gained from the power supply.

If components are in parallel, then the voltage loss through each equals the voltage supply.

The voltage loss to parallel components is identical.

Summary of current and voltage in circuits

In a series circuit:

☐ the current is the same everywhere around the circuit

☐ each component loses a share of the voltage gain

☐ the voltages lost to components add up to equal the voltage gain.

In a parallel circuit:

☐ each branch receives a share of the current from the power supply

☐ the currents in branches add up to equal the current supplied

☐ the voltage lost to each component is the same as the voltage supply.

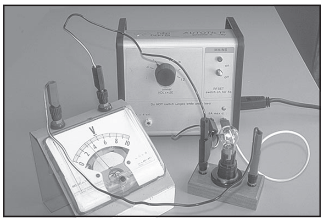
Activity 2 Using a voltmeter

To measure the voltage gain or loss as the current travels through a component, the voltmeter is connected across that component. It is connected in parallel with the component. A meter that can measure voltage in a direct current circuit will have a red positive terminal and a black negative one. The connection to the red meter terminal must lead back to the positive power supply terminal.

Steps

1 Set up/turn off
2 Select scale
3 Locate component
4 Connect meter in parallel
5 Check +ve to +ve
6 Test meter
7 Take reading

Steps:



1 Set up the circuit. Make sure it works, then switch off.

2 If you are using a digital multimeter, turn the dial to the 10 or 20 V DC setting. If an analogue meter has several red terminals, use the terminal with the highest range to start with.

3 Identify the component that you wish to find the voltage gain or loss as the current passes through it.

4 Use wires or probes to connect the meter to the connection points on the component.

5 Check the connection from the red meter terminal leads towards the positive terminal of the power supply.

6 Turn on the circuit. If the needle flicks backwards, quickly turn the circuit off and reverse the connections. A digital meter gives a negative reading if connected wrongly.

7 Take the reading in volts off the display or scale. Decide whether a voltage gain or loss is involved.

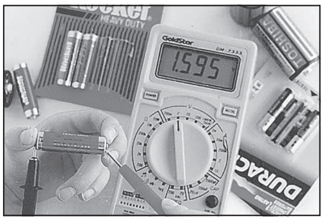
Activity 3

1 Match up descriptions with terms.

a electrons	**A** used to measure the current flowing in a circuit
b conductor	**B** a flow of electrical charge
c charge	**C** a meter that provides the reading in digits
d coulomb	**D** extremely small particles with a negative charge
e current	**E** potential energy used by a component
f ampere or amp	**F** a circuit in which components are in several branches
g ammeter	**G** the unit for voltage gain or loss
h analogue meter	**H** substance that allows electrons to flow through freely
i digital meter	**I** energy gained or lost by electrons in the current
j series circuit	**J** objects that oppose the flow of current
k parallel circuit	**K** a property that is either positive or negative
l resistance	**L** potential energy provided by a power supply
m terminal	**M** the unit for charge
n voltage gain	**N** a meter used to measure voltage gain or loss
o voltage loss	**O** a circuit in which all components are in the same loop
p voltage	**P** a meter that has a scale and a marker
q volt	**Q** a connection point on a component
r voltmeter	**R** the unit for current

2 Explain the difference between:

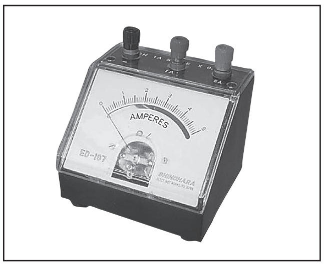
- **a** electrical charge and current
- **b** an analogue and a digital meter
- **c** current and voltage
- **d** voltage supply and voltage loss
- **e** a component and a terminal.



3 Copy and complete the following statements.

a Current is a flow of electrical __________. The charge is carried by __________ along __________. The symbol for current is _____ and the unit is the __________ or __________ (A). The size of the current is measured using an __________. The current is driven by an electrical __________ __________ created by the __________ supply.

b Voltage is related to the __________ energy gained or lost by __________ in the __________. When the current passes through a __________ supply, a voltage __________ occurs. When it passes through a component, a voltage __________ can occur. The symbol for voltage gain or loss is ____ and the unit is the __________ (V). Voltage gain or loss is measured using a __________.



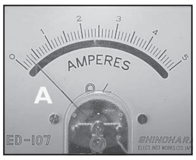
4 Study the meter and answer the questions.

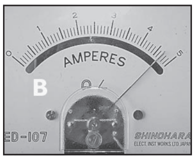
- **a** Is this meter an ammeter or voltmeter?
- **b** Is it an analogue or digital meter?
- **c** What units does it measure in?
- **d** Why does it have two red terminals?

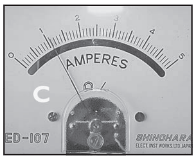
5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** Current is a flow of electrical charge.
- **b** 6 250 000 000 000 000 000 electrons are needed to give one coulomb.
- **c** An analogue meter has an electronic numerical display.
- **d** In a series circuit, the current is constant everywhere.
- **e** In a parallel circuit, the current is shared out amongst the branches.
- **f** In a parallel circuit, the branch with the greatest resistance gets the biggest share of the current.
- **g** With a DC meter, the lead from the red terminal must lead back to the negative terminal of the power supply.
- **h** An electrical force field drives electrons around a circuit and provides them with potential energy.
- **i** In a series circuit, components use a share of the voltage supply.
- **j** In a parallel circuit, the voltage loss across each component equals the voltage gain.

6 With an analogue meter, the reading is taken to the nearest mark. Study the readings, then answer the questions.





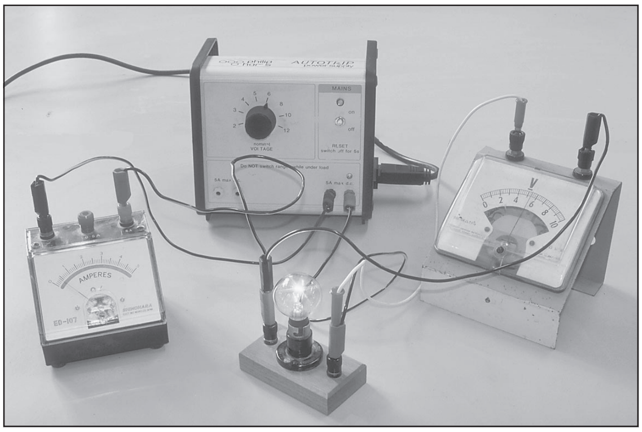


- **a** What type of meter is it and what units does it measure in?
- **b** What is the range of this meter?
- **c** The space between two marks on the scale is called the interval. How large is the interval on this meter?
- **d** How accurately can this meter be read to?
- **e** What is the reading on each to the nearest one decimal place?

7 Look through the instructions for using an ammeter and voltmeter in Activities 1 and 2, then answer these questions.

- **a** How is an ammeter connected to measure current through a component?
- **b** How is a voltmeter connected to measure voltage loss across a component?
- **c** Where must the wire connected to the red terminal of a direct current meter lead to?

8 Study this circuit which was set up to measure the current travelling through the bulb and the voltage loss across the bulb. Then answer the questions below.



- **a** Trace the wires from the ammeter. Is the meter connected in series or parallel with the lamp?
- **b** Which terminal of the power pack does the wire from the positive (red) terminal of the ammeter lead towards?
- **c** How can you tell that the ammeter connections are the right way around?
- **d** What is size of the current passing through the bulb?
- **e** Trace the wires from the voltmeter. Is this meter connected in series or parallel with the lamp?
- **f** Which terminal of the power pack does the wire from the positive (red) terminal of the voltmeter lead towards?
- **g** What is the voltage drop across the bulb?
- **h** What is the voltage supply from the power pack set to?
- **i** Is the voltage loss across the bulb equal to or less than the voltage supplied by the power pack? Suggest a reason to account for any difference.

9 Read the passage below, then answer the questions that follow.

Solar cells

A cell is a device that transforms another type of energy into electricity.

Chemical cells, such as torch batteries, transform chemical energy into electrical energy.

Solar cells transform light into electrical energy. The efficiency of current cells is about 30%.

These cells are used to power satellites, calculators and remote scientific instruments.

Solar cells are able to use an abundant free energy source, sunlight, but cease to work after dark. A solar cell needs a relatively large surface area to absorb sufficient light to produce the required current.

Solar cells are flat and consist of two thin layers of different semiconductor materials.

Light waves, which penetrate the panel, free up electrons at the junction between layers. These free electrons move to the top layer creating a positive charge zone near the junction. This zone attracts the negatively charged electrons up from the bottom layer.

This causes the top layer to become a negative terminal, and the bottom layer to become a positive terminal. When the two terminals are connected in a circuit, they create an electrical force field that drives the current and provides a voltage gain.

a What is a cell?

b What is the difference between a chemical and a solar cell?

c If 20 joules of light energy fall on a solar cell, how much electrical energy could the cell gain?

d Why are solar cells used to power satellites and remote instruments?

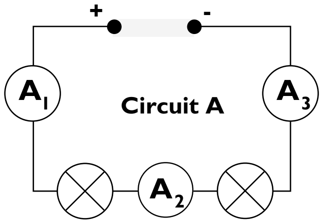
e What are advantages of solar cells?

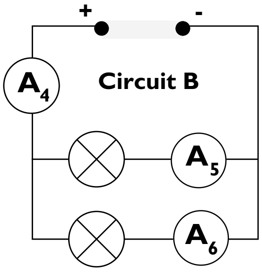
f What are disadvantages of solar cells?

g What is a semiconductor?

h How is an electrical force field created by a solar cell?

i When the solar cell is connected in a circuit, what two things occur?





10 In order to answer the questions below you will need to refer to the summary on page 132.

a Are the bulbs in circuit A in series or parallel?

b If the current passing through ammeter A1 is two amps, what will be the current in ammeters A2 and A3?

c Are the bulbs in circuit B in series or parallel?

d If the current in A5 and A6 is three amps, what is the current in A4?

e Write a statement comparing what happens to the current in series and parallel circuits.

11 To answer the questions refer to the summary on page 132. Each cell causes a voltage gain of 1.5 V and the lamps are identical.

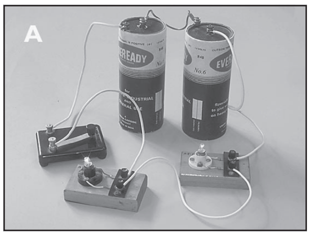
a Are the lamps in circuit A in series or parallel? The cells?

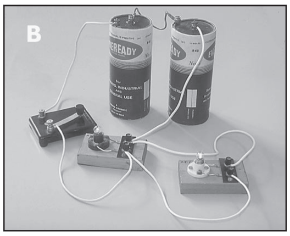
b In A, what is the voltage gain from the two cells?

c What voltage loss will occur across each lamp in A?

d Are the lamps in circuit B in series or parallel? The cells?

e What voltage loss will occur across each lamp in B?





Unit

20

Resistance, Power And Energy

Learning outcomes

On completing this unit you should be able to:

☐ Define resistance **R** in terms of the voltage lost by the current

☐ Use the formula **R = V ÷ I** to calculate a component's resistance

☐ Interpret a voltage-current graph and relate it to Ohm's Law

☐ Define power **P** and use the formula **P = V x I** to find power

☐ Set up a circuit to find the resistance and power of a component

Resistance and current

Electrons in a current can travel with ease through a **conductor** such as a copper wire and little electrical energy is lost.

But some substances are much more difficult for electrons to pass through. This opposition to the **current** is called resistance. A substance with resistance limits the flow of electrons.

A circuit component that is specifically designed to limit the current is called a **resistor**. There are fixed resistors and variable resistors such as a **rheostat** and a dimmer.

If the resistance in a circuit is increased, then the current passing through it will fall. If the resistance is decreased, the current will increase.

As the current struggles to travel through a resistor, some of its electrical energy is changed into heat and a voltage loss occurs. In opposing the current, a resistor transforms electrical energy into heat.

Finding the resistance

Resistance, symbol **R**, can be defined as the **voltage lost** by each **ampere** of current. The unit in which resistance is measured is the **ohm**, symbol **W**. One ohm is a voltage loss of 1 **volt** from every ampere of current.

The resistance of a component such as a lamp can be found by measuring the voltage loss **V** across it and the current **I** passing through it.

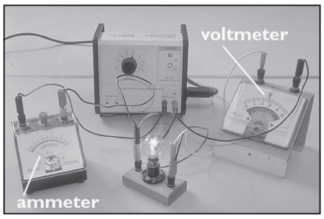


Figure 20.1 To measure resistance, a voltmeter is connected in parallel with the lamp and an ammeter in series with it.

The resistance is calculated using this formula:

Resistance = voltage ÷ current

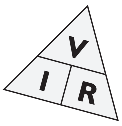
$$R = \frac{V}{I}$$

❑ Voltage must be in volts (V) and current in amps (A) to give resistance in ohms (W).

To find the current passing through a resistor (or the voltage drop across it) when the resistance is known, modify the formula to give:

I = V ÷ R or **V = I x R**

❑ The triangle opposite gives different forms of the formula.



Voltage and current

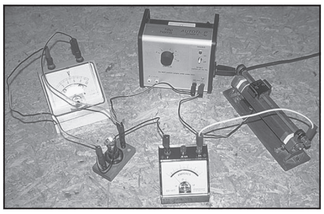
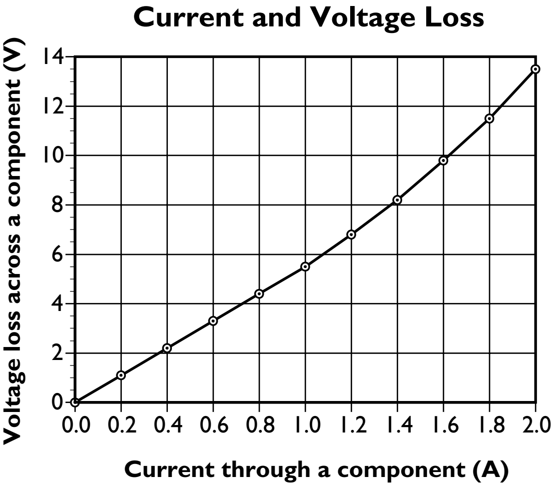


Figure 20.2 Voltage loss across a resistor

This circuit can be set up to show what happens to the voltage loss across a resistor (lamp) if the current through it is increased.

The rheostat is used to increase the size of the current passing through the resistor (lamp), which is measured by the ammeter. The voltmeter measures the resulting voltage loss across the resistor.

The voltage loss is plotted against the current on the graph opposite. Increasing the current passing through the resistor (lamp) causes the voltage loss to rise. So voltage loss is proportional to the current.



The slope of a voltage-current graph represents the resistance of the resistor. If the slope is a straight line, then the resistance of the resistor is constant. On the graph opposite, the line is straight initially but then curves upwards. This means the resistance is constant at first, but then it begins to increase.

The reason why the resistance increases is because the resistor is heating up. Some of the electrical energy is transformed into heat. When the temperature of a resistor rises, electrons find it more difficult to pass through, so its resistance increases. For the resistance to remain constant, the resistor must be kept at a constant temperature.

Ohm's Law

Ohm's Law states that the voltage loss across a resistor is directly proportional to the current through it, provided the temperature of the resistor stays constant.

Directly proportional means that the voltage loss will double, say, when the current doubles.

Power and energy

Components such as lamps, heaters and motors transform electrical energy into light, heat or kinetic energy. **Energy**, symbol **E**, is measured in units called **joules** (J).

Electrical energy can be transformed slowly or rapidly, depending on the **power rating** or **wattage** of the component. If the component transforms a lot of energy per second, then it has a high power rating. If it transforms little energy per second, then it has a low power rating.

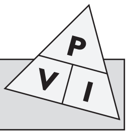
Power, symbol **P**, is defined as the rate at which energy is supplied or used. The unit for power is the **watt** (W). One watt is equal to 1 joule of energy being transformed per second. For objects with larger power ratings, kilowatts are used instead:

1 kW = 1000 W

If the voltage supplied to a component increases, then the component will transform more energy. If a component receives more current, then it will also transform more energy as more electrons with electrical energy are passing through. So, power is proportional to both voltage and current.

The power of a component can be found by connecting an ammeter in series with it and a voltmeter in parallel around it (same circuit as for resistance). Power is calculated by:

Power = voltage x current $P = V \times I$



To find the current passing through a component (or the voltage drop across it) when the power is known, modify the formula to give:

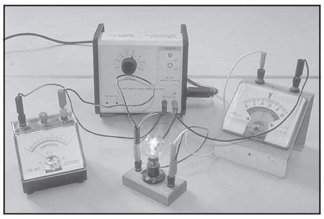
$\mathbf{I = P \div V}$ or $\mathbf{V = P \div I}$

To find the **total energy E** lost or used by a component over a period of time, multiply its power rating by the time it has been operating:

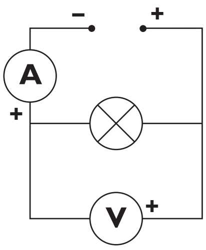
Total energy = power x running time $E = P \times t$

❑ Power must be in watts and time in seconds to give energy in joules.

Activity 1 Finding resistance and power



To find the resistance and power rating of a component such as a lamp, the circuit below is used. The lamp is connected to a suitable power supply. An ammeter is connected in series with the lamp, and a voltmeter is connected in parallel around the lamp.



Steps:

1 Take the current reading off the ammeter scale: **I** = 0.5 A

2 Record the voltage loss off the voltmeter scale: **V** = 5.5 V

3 To calculate the resistance of the lamp, use the formula: $\mathbf{R = V \div I}$

4 Enter the values into the formula, then complete the calculation using your calculator:

R $\boxed{=}$ 5.5 $\boxed{\div}$ 0.5 $\boxed{=}$ 11

5 Record the resistance using the appropriate unit: **R** = 11 **Ω**

6 To calculate the power of the lamp, use the formula: **P = V x I**

7 Enter the values into the formula then complete the calculation using your calculator:

P $\boxed{=}$ 5.5 $\boxed{x}$ 0.5 $\boxed{=}$ 2.75

8 Round off your answer to the nearest decimal place and record the power used by the lamp using the appropriate unit: **P** = 2.8 W

Activity 2

1 Match up descriptions with terms.

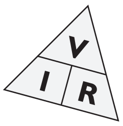
a electrons	**A** unit of current
b conductor	**B** opposition to the flow of electrons
c current	**C** unit of energy
d resistor	**D** substance that allows electrons to flow through it freely
e rheostat	**E** unit of power
f resistance	**F** required to be able to do work
g voltage loss	**G** unit of resistance
h ampere	**H** rate at which electrical energy is supplied or used
i volt	**I** a resistor whose resistance can be varied
j ohm	**J** another term for power rating
k Ohm's Law	**K** electrical energy lost by electrons in the current
l energy	**L** negatively charged particles which flow in a current
m joule	**M** energy used by a component over a period of time
n power rating	**N** a flow of charged particles such as electrons
o wattage	**O** voltage is proportional to current if the temperature is constant
p power	**P** the wattage of a component
q watt	**Q** unit of voltage gain or loss
r total energy	**R** a component that is designed to limit current flow

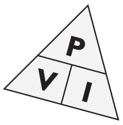
2 Explain the difference between:
- **a** a conductor and a resistor
- **b** a fixed resistor and a rheostat
- **c** resistance and power
- **d** total energy and power.

3 Copy and complete the chart below, which summarises different electrical quantities.

Quantity	Symbol	Unit Name	Unit Symbol
Current	**I**	ampere	A
Voltage			
Resistance			
Power			

4 Use the formula triangles to identify the formula to be used in the following situations.



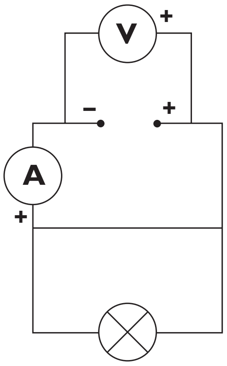


- **a** resistance of an object given current and voltage loss
- **b** power of an object given voltage loss and current
- **c** current through an object given resistance and voltage loss
- **d** voltage loss given power and current.

5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

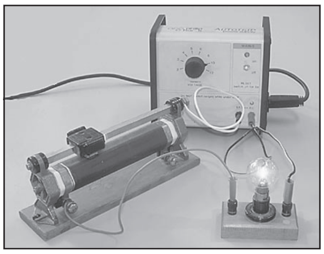
- **a** Electrons can travel through a conductor without losing much energy.
- **b** If the resistance in a circuit is increased, then more current will flow.
- **c** A resistor converts electrical energy into heat energy.
- **d** An ohm is a voltage loss of one volt from each ampere of current.
- **e** If the current through a component is increased, then the voltage loss across it will increase also.
- **f** The slope of a voltage-current graph represents the resistance of a component.
- **g** If the slope of a voltage-current graph is a straight line, then the resistance of the component is constant.
- **h** The power rating of a component in a circuit is how fast it supplies or uses electrical energy.
- **i** Power is only proportional to current.
- **j** An object with a high power rating will convert lots of energy each second.

6 The circuit shown in the diagram opposite was set up to investigate what happens to the current when the voltage supply is increased. The voltage was increased using the voltage selector knob on the power pack and checked using the voltmeter. The resulting current was measured using the ammeter.



- **a** From the data, describe what happens to the current as the voltage is increased.
- **b** Is the current proportional to the voltage gain?
- **c** Draw a line graph of the data.
- **d** Describe the shape of the graph.
- **e** Suggest a reason why the current does not increase as much at higher voltage settings.
- **f** How has the bulb affected the current in the circuit?

Voltage (V)	Current (A)
0	0
1.8	0.4
3.6	0.8
5.4	1.2
7.2	1.6
9.0	1.9
10.8	2.1



7 In the circuit opposite, the voltage loss across the bulb was 10.2 V and the current in the circuit was 2.5 A. The circuit was on for 90 seconds.

- **a** What formula would you use to find the bulb's resistance?
- **b** Calculate the resistance of the bulb to the nearest decimal place. Give the unit as well.
- **c** What formula would you use to find the electrical power supplied to the bulb?
- **d** Calculate the electrical power used by the bulb to the nearest decimal place. Give the unit as well.
- **e** What formula would you use to find the total energy used by the bulb?
- **f** Calculate the total energy used by the bulb to the nearest decimal place. Give the unit as well.
- **g** If only 10% of the electrical energy is converted into light, how many joules of light energy will have been emitted?
- **h** How many joules of heat energy will the bulb have produced?

8 Copy and complete the chart by finding the power used by each appliance given the voltage supply and current.

Appliance	Voltage (V)	Current (A)	Power (W)
Toaster	240	4.0	
Television	240	0.2	
Shaver	6	0.5	
Radio	3	0.5	
Fan	240	2.0	
Lamp	240	0.3	

9 Read the passage below, then answer the questions that follow.

Power Costs

Appliances that are plugged into the mains use electricity, which must be paid for. On the power board of your house there is a meter that measures the amount of electrical energy used.

The meter measures in units called **kilowatt-hours**. One kilowatt-hour is the amount of energy used by a one kilowatt appliance in one hour.

If a 1 kilowatt fridge was switched on for one hour, then the total energy it would use is given by the formula:

Total energy = power x running time

But power must be in watts and running time in seconds:

1 kilowatt = 1000 watts

1 hr = 60 min and 1 min = 60 s

So 1 hr = 60 x 60 s = 3600 s

So the total energy used by the fridge during one hour is:

Total energy = 1000 × 3600

= 3 600 000 J

So a one kilowatt fridge uses 3 600 000 joules every hour. A two kilowatt fridge uses 7 200 000 joules of energy per hour.

The meter on your power board records the running total of kilowatt-hours used by all circuits in the house.

Every month a reading is taken from the meter and a calculation is made of the kilowatt-hours used. Your family is then is billed for the kilowatt-hours used. The current typical cost per kilowatt-hour is 60 sene.

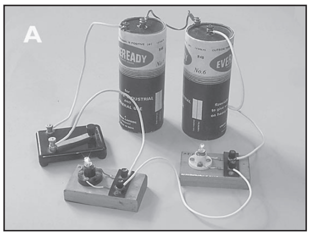
- **a** What is meant by 'mains electricity'?
- **b** What unit is the electrical energy usage of a house measured in?
- **c** How many joules of energy are equal to one kilowatt-hour?
- **d** If a two kilowatt heater is left on overnight for 10 hours, how many kilowatt-hours of electricity will it use?
- **e** How many joules of energy will the heater use in that time?
- **f** What will be the cost of the electricity used overnight by the heater?
- **g** What is the advantage and disadvantage of having a hot water cylinder operating on a night-time rate?

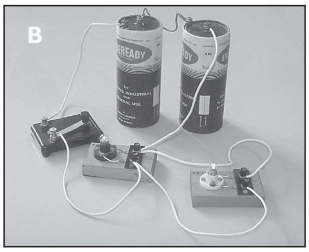
10 Copy and complete the chart by finding the total resistance of each appliance given the voltage supply and current.

Appliance	Voltage (V)	Current (A)	Resistance (Ω)
Toaster	240	4.0	
Television	240	0.2	
Shaver	6	0.5	
Radio	3	0.5	
Fan	240	2.0	
Lamp	240	0.3	

11 Two identical bulbs were connected to two cells. In circuit A, the bulbs are connected in series. In circuit B, they are connected in parallel. The two cells provide a total voltage gain of 3 V.

- **a** What would be the voltage loss across each bulb in circuit A?
- **b** If the current flowing in A was 0.5 A, what would be the resistance of each bulb?
- **c** What would be the total resistance of the two bulbs in A? (Individual resistances are added in series circuits.)
- **d** In circuit B, the voltage loss across each bulb is 3 volts; what will be the current flowing through each?
- **e** What would be the total current flowing in circuit B? (Remember that the currents in parallel circuits are added to give the total current.)





Unit 21

Speed And Acceleration

Learning outcomes

On completing this unit you should be able to:

- ☐ Define speed and acceleration
- ☐ Provide the appropriate units for speed and acceleration
- ☐ Use formulas to calculate average speed and acceleration
- ☐ Plot and interpret distance-time and speed-time graphs
- ☐ Develop a problem solving method and calculate the slope of a graph

Describing motion

An object is in **motion** if its location is changing. At this level, you will only deal with objects moving in a straight line.

Motion can be described using words, numbers or a graph.

- ☐ **Distance**, symbol **d**, is used to describe *how far an object has travelled from the starting point*. The units are metres (m) or kilometres (km).
  1 km = 1000 m
- ☐ **Time**, symbol **t**, is used to describe *how long a journey has taken*. The units are seconds (s), minutes (min) and hours (hr).
- ☐ **Speed**, symbol **v**, is used to describe *how fast an object is travelling*. (**v** also stands for velocity – the speed of an object in a particular direction.) The scientific units for speed are metres per second (written as m/s or m s^{-1}).
- ☐ **Acceleration**, symbol **a**, is used to describe *how an object's speed is changing*. The units are metres per second squared (m/s^2 or m s^{-2}).
- ☐ An accelerating object is speeding up, a decelerating object is slowing down. **Deceleration** is shown by a minus sign (e.g. –10 m s^{-2}).

Finding the speed of an object

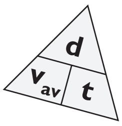
You can either find the speed of an object at one point of time, or the average speed of the object over a journey (or part of a journey).

The **instantaneous speed (v)** of an object can be found using a speedometer or a speed camera or speed gun. The instrument will give the units.

During a journey an object's speed may vary. The **average speed v_{av}** of an object over a journey (or part of a journey) can be found using a formula or from a distance-time graph.

To calculate v_{av} you measure the distance travelled and the time taken, then apply the formula:

$$\textbf{Average speed} = \frac{\textbf{distance travelled}}{\textbf{time taken}} \qquad v_{av} = \frac{d}{t}$$



Note: the units for speed depend on the units used for distance and time.

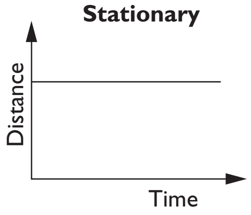
To change between metres per second and kilometres per hour use these conversions: $\mathbf{m\ s^{-1} = 0.28}$ x $\mathbf{km\ hr^{-1}}$ and $\mathbf{km\ hr^{-1} = 3.6\ x\ m\ s^{-1}}$

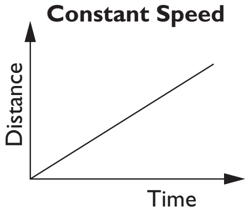
Interpreting distance-time graphs

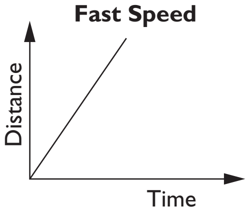
On a **distance-time motion graph**, the distance an object has travelled from the starting point is plotted against time since the start of the journey.

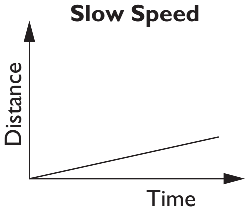
The **gradient** (slope) of the line gives information about the object's speed:

- ☐ a horizontal line means it is stationary
- ☐ a straight sloping line means constant speed
- ☐ a steep straight line means fast constant speed
- ☐ a gentle straight line means slow constant speed.


Stationary

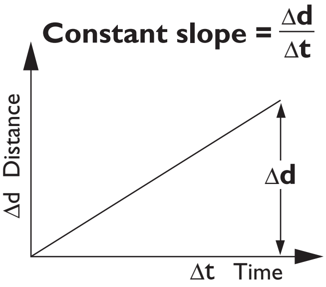

Constant Speed


Fast Speed


Slow Speed

The **gradient** or **slope** can be calculated by: (Δ means 'change in')

$$\textbf{Slope} = \frac{\textbf{change in distance}}{\textbf{change in time}} = \frac{\Delta d}{\Delta t}$$



As this is the same formula used to calculate average speed (v_{av}), the slope of a distance-time graph gives the object's average speed.

Finding the acceleration of an object

It is possible to find the **instantaneous acceleration** of an object at one point of time, or the average acceleration of an object over a journey (or part of a journey).

The instantaneous acceleration of an object can be measured using an **accelerometer**, but these instruments are not very common.

The **average acceleration** of an object over a journey (or part of a journey) can be found using a formula or from a speed-time graph.

At this level you will only consider objects travelling in a straight line with constant acceleration or constant deceleration.

To calculate acceleration, you need to measure the initial speed, the final speed at the end of the journey and the time taken for the journey. This formula is then applied:

(Δ means 'change in'.)

$$\textbf{Acceleration} = \frac{\textbf{change in speed}}{\textbf{change in time}} \qquad \mathbf{a} = \frac{\Delta \mathbf{v}}{\Delta \mathbf{t}}$$

$$= \frac{\textbf{final speed – initial speed}}{\textbf{time taken}}$$

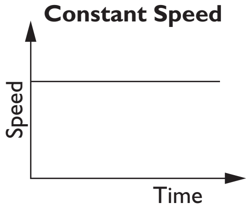
In problems, speed will be in metres per second (m s^{-1}) and time in seconds (s), so acceleration will be in metres per second squared (m s^{-2}).

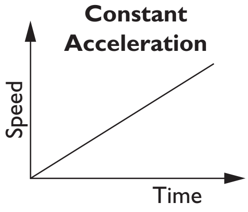
Interpreting speed-time graphs

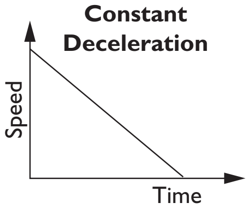
On a **speed-time motion graph**, the instantaneous speed of an object is plotted against time since the start of the journey.

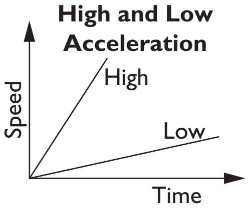
The slope of the graph gives information about the object's acceleration:

- ☐ a horizontal line means constant speed
- ☐ a straight upward-sloping line means constant acceleration
- ☐ a straight downward-sloping line means constant deceleration
- ☐ a steep upward-sloping line means high acceleration
- ☐ a gentle upward-sloping line means low acceleration.









The graph **gradient** or **slope** can be calculated using this formula:

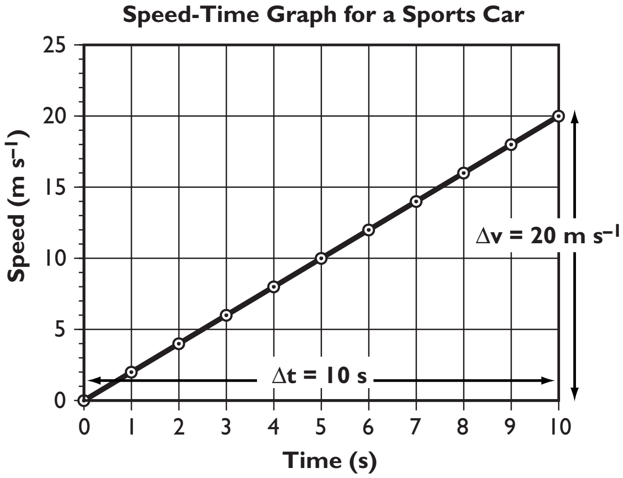
$$\textbf{Slope} = \frac{\textbf{change in speed}}{\textbf{change in time}} = \frac{\Delta \mathbf{v}}{\Delta \mathbf{t}}$$

In the example below:

$$\text{Slope} = \frac{\Delta v}{\Delta t} = \frac{20 \text{ m s}^{-1}}{10 \text{ s}} = 2 \text{ m s}^{-2}$$

As this is the same formula that is used to calculate acceleration, the slope of a speed-time graph gives an object's acceleration.

The area under a speed-time graph represents the distance travelled by the object during the journey. Simple geometry can be used to find the area.



Activity 1 Problem solving method

You will be asked to solve problems by applying a formula. It is important to develop a method to ensure you get the right answer each time.

Problem:

The men's world record for swimming 1.5 km is 14 min 43 s. What would his average speed in m s^{-1} have been? Round off your answer to two decimal places (2 dp).

Applying a method:

1 Write down what you have to find: speed in m s^{-1} to two decimal places

2 Write down **quantities** given: d = 1.5 km and t = 14 min 43 s

3 Write down the **formula** you will need to use:

$$\mathbf{v_{av} = \frac{d}{t}}$$

4 Change the quantities into the appropriate **units**:
1.5 km = 1500 m
14 min 43 s = (14 x 60) + 43 = 883 s

5 Substitute these quantities into the formula:

$$\mathbf{v_{av}} = \mathbf{\frac{d}{t}} = \frac{1500 \text{ m}}{883 \text{ s}}$$

6 Use your calculator to find the correct answer:
1500 $\boxed{\div}$ 883 $\boxed{=}$ 1.6987542

7 Next **round off** your answer to two decimal places:
$\boxed{1.69}$87542 = 1.70 (2 d.p.)

8 Finally record your answer with the correct units:
v_{av} = 1.70 m s^{-1}

Solution Checklist

1 State your task
2 Write down quantities
3 Identify the formula
4 Modify units
5 Substitute in formula
6 Complete calculation
7 Round off answer
8 Give answer and units

Activity 2

1 Match up definitions with terms.

a motion	**A** speed of an object at one point of time
b distance	**B** describes how an object's speed is changing
c time	**C** graph where distance gone is plotted against time
d speed	**D** used to measure instantaneous acceleration
e acceleration	**E** the act of moving from one location to another
f deceleration	**F** acceleration of an object at one point of time
g instantaneous speed	**G** an amount of something which is measurable
h average speed	**H** describes how far an object has travelled
i distance-time graph	**I** the slope of a graph line
j gradient	**J** mean speed over a journey
k instantaneous acceleration	**K** a mathematical relationship between quantities
l accelerometer	**L** describes how long a journey has taken
m average acceleration	**M** reducing to a certain number of decimal places
n speed-time graph	**N** what physical quantities are measured in
o quantity	**O** describes how fast an object is travelling
p units	**P** graph where speed is plotted against time
q formula	**Q** mean acceleration over a journey
r rounding off	**R** when the speed of an object is decreasing

2 Explain the difference between:

- **a** a speedometer and an accelerometer
- **b** acceleration and deceleration
- **c** instantaneous and average speed
- **d** negative and positive acceleration.

3 For each quantity, match up its symbol, the unit it is measured in and the symbol for that unit.

Quantity	**Symbol**	**Scientific Unit**	**Symbol**
distance	v	metres per second	m
time	d	metres	m s^{-1}
speed	a	metres per second squared	s
acceleration	t	second	m s^{-2}

4 Using the conversions below, change kilometres per hour into metres per second and vice versa. Round off the values to one decimal place.

Speed	Speed
10 km hr^{-1}	
50 km hr^{-1}	
80 km hr^{-1}	
100 km hr^{-1}	
	1 m s^{-1}
	5 m s^{-1}
	10 m s^{-1}

m s^{-1} = 0.28 x km hr^{-1}

km hr^{-1} = 3.6 x m s^{-1}

5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

a A stationary object is no longer in motion.

b One metre is one thousandth of a kilometre.

c The symbol **v** can represent speed or velocity.

d Positive acceleration means an object is getting faster, negative acceleration means it is reversing.

e Deceleration is another word for negative acceleration.

f A speed camera measures the average speed of cars.

g The average speed on a journey will usually be less than the highest speed and greater than the lowest speed.

h The slope of a distance-time graph gives an object's average speed.

i To calculate acceleration you need to know initial and final speeds as well as time taken.

j The gradient of a speed-time graph gives an object's speed.

k Constant speed means zero acceleration.

6 A triathlon involves swimming, cycling and running.

The distances for each event in a triatholon and the fastest time for that event are recorded in the chart below. Calculate the top competitor's average speed in each event in metres per second. Round your answers off to one decimal place.

Event	Distance	Fastest Time	Speed (m s^{-1})
swimming	4000 m	2610 s	
cycling	120 km	9605 s	
running	32 km	9913 s	

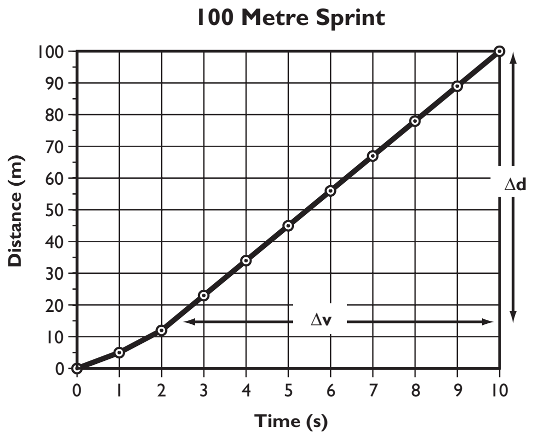
a Why is it important that each speed is calculated in the same units?

b What alternative units for speed could have been used?

c Rank the events from the fastest to the slowest average speeds.

d Suggest reasons why such different speeds are reached.

7 The world record for a 100 m sprint is just under 10 s. The distance travelled in each second was electronically recorded and plotted on the graph.



a What type of graph is this?

b What does the straight section of the graph from the second to the tenth second show?

c What does the initial upward-curving part of the graph indicate?

d At t = 2 s the distance travelled was 12 m. Find the slope of the graph during the period from the second to the tenth second (to 1 d.p.).

e What was the average speed of the sprinter between the second and tenth seconds (to 1 d.p.)?

f What was the average speed of the sprinter over the whole journey (to 1 d.p.)?

g Why are the results from **e** and **f** above slightly different?

8 The speed of two racing cars taking off from a standing start was recorded for 10 s.

a Plot the speed of the cars against time on the same graph.

b Compare the acceleration trends.

c Calculate the slope of each line.

d What is the acceleration of each car?

Time	Car A Speed	Car B Speed
0 s	0 km hr^{-1}	0 km hr^{-1}
1 s	10 km hr^{-1}	5 km hr^{-1}
2 s	25 km hr^{-1}	15 km hr^{-1}
3 s	45 km hr^{-1}	30 km hr^{-1}
4 s	65 km hr^{-1}	45 km hr^{-1}
5 s	85 km hr^{-1}	60 km hr^{-1}
6 s	105 km hr^{-1}	75 km hr^{-1}
7 s	125 km hr^{-1}	90 km hr^{-1}
8 s	145 km hr^{-1}	105 km hr^{-1}
9 s	165 km hr^{-1}	120 km hr^{-1}
10 s	185 km hr^{-1}	135 km hr^{-1}

9 Read the passage below, then answer the questions that follow.

Human speed limits

As track athletes have become more highly trained and fitter, the times for field events have continued to fall. For example, the fastest time for a 100 m sprint is 9.79 s, recorded during a relay event in 1988.

If times for events are dropping, that means the speeds the athletes are reaching must be increasing. The maximum speed reached in that relay was 12.05 m s^{-1} or 43.37 km hr^{-1}; it occurred between 40 and 50 metres from the start.

But these increases in speed are usually very small and it may be that an upper speed limit will eventually be reached.

What is it that prevents athletes from going faster and faster? As an athlete races along a track, they apply a thrust force to the track through their running shoes. This thrust force produces an equal and opposite reaction force from the track that propels the athlete forward.

If these were the only forces involved, then the athlete would get faster and faster along the track. But in most short track events top speed is reached within four to five seconds and the athlete continues at that speed for the rest of the race. What force is acting to prevent the athlete from accelerating further?

As the athlete takes off, the air in front is compressed then pushed away on either side. As the air is compressed, it pushes back against the athlete. This new force is called air friction or drag and it opposes the thrust force thus reducing acceleration.

As the athlete's speed increases, more air is compressed in front, which increases the force of air friction. This force increases rapidly with speed until it equals the thrust force of the athlete. At this point no further acceleration is possible. The athlete can only carry on at a constant speed as the two forces (drag and thrust) are now in balance.

The strength of the drag force is also affected by the turbulence of air as it passes around the athlete's body. Wearing tight-fitting or streamlined clothing reduces drag and allows a little extra speed.

a What is the fastest average speed reached over a 100 m sprint?

b Why would the average speed in a race be less than the maximum speed reached?

c What distance did the sprinter cover before reaching maximum speed?

d What force is involved in pushing a sprinter forward?

e What causes air friction or drag?

f When thrust is greater than drag, what happens to the athlete's speed?

g When drag is equal to thrust, what happens to the athlete's speed?

10 The speed of a remote controlled model racing car was recorded every second during a 10-second period. The results were plotted on the graph.

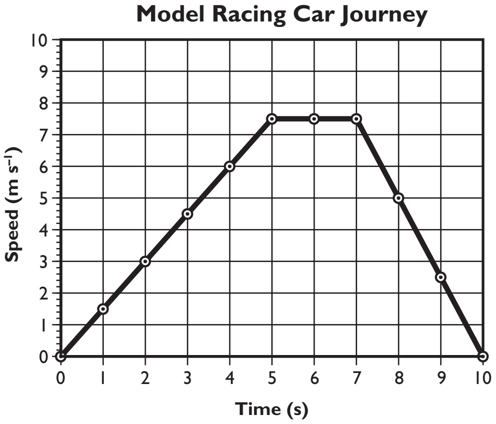
a What type of graph is this?

b What information does the slope of this type of graph provide?

c Interpret the shape of the graph in the three different stages.

d Calculate the acceleration of the car during the first five seconds.

e What is the acceleration of the car during the fifth and sixth seconds?



f Calculate the acceleration of the car during the last three seconds.

11 Use the steps outlined in the activity on page 147 to find the solution to these problems.

a The farmer took 12 min to plough a furrow 3250 m long. Find the average speed of the tractor to one decimal place.

b The jet plane accelerates in a straight line into the sky when it leaves the runway. As its tyres left the ground the plane was travelling at 62 m s^{-1}; 11 seconds later it was travelling at 140 m s^{-1}. Calculate the plane's acceleration to two decimal places.

c The train decelerates from 100 km hr^{-1} to a standstill in 25 s. Calculate its acceleration in m s^{-2} to two decimal places.

Unit 22

Force, Mass And Momentum

Learning outcomes

On completing this unit you should be able to:

- ❑ Describe the effects of force on motion
- ❑ Define force and its units
- ❑ Compare the effects of balanced and unbalanced forces
- ❑ Use the formula: **F = m x a** and distinguish between weight and mass
- ❑ Explain what momentum is and use the formula: **momentum = m x v**
- ❑ Modify a formula into the form that you require

Changing motion

What is needed to make a stationary object move? A push or pull or twist must be applied. These actions are called **forces**.

A force is something that can change the motion of an object. An object's speed or direction of motion may be changed by applying a force.

Forces can also squash or stretch fixed objects. In this unit you will be concerned with the effect of forces on free objects only.

A force is not necessarily needed to keep an object moving – a squash ball keeps moving after it has been hit. But most moving objects slow down because of friction. In the absence of friction a moving object keeps on moving.

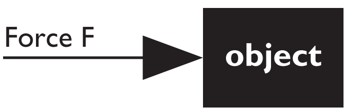
When a force is applied to a stationary object and makes it move, the object gains **kinetic energy**. So a force can transfer energy to an object.

If the object applying a force must touch another object to make it move, then the force is called a **contact force**.

There are also **non-contact forces** that act over a distance. The object creating the force does not need to touch the object that the force is applied to. Magnetism and gravity are non-contact forces.

Measuring forces

Before defining the unit of force, you need to recall what mass is. The **mass** of an object is the amount of matter in the object. Mass is given the symbol **m** and is measured in units called **kilograms** (symbol **kg**).



The symbol **F** is used to represent force. On diagrams, forces are drawn with arrows

Figure 22.1 Force meter

indicating the **direction** in which the force acts. The length of the arrow indicates the **magnitude** (strength) of the force.

The strength of a force is measured in **newtons** (symbol **N**). A one newton force is defined as the force needed to make a free 1 kg object accelerate at 1 m s^{-2} in the absence of any opposing force.

The size of a force is measured using a spring. A spring will compress or extend a fixed distance related to the size of the force. A **force meter** contains a spring with a marker attached. The position of the marker indicates the magnitude of the force on the scale.

Combining forces

Different forces can act on an object. These include:

- **thrust** – the force that is intended to make the object move
- **friction** – the force that opposes the motion of the object
- **weight** – the downwards pull of gravity on the object
- **support** – the upwards push of the surface on which the object rests.

The **net force** acting on an object can be found by combining forces.

If two forces act in the same direction, then you add the forces to get the net force. If two forces act in opposite directions, then you subtract the smaller force from the larger one to get the net force.

When the net force is zero (balanced forces), the object is in **equilibrium**.

Balanced Forces

Net force = 10N – 10N = 0N

If two equal-size forces act in opposite directions on an object, then the net force is zero. ***Balanced forces*** *do not change an object's motion.*

Unbalanced Forces

Net force = 15N – 10N = 5N to right

If a pair of opposing forces are unequal, then the net force is not zero. ***Unbalanced forces*** *will cause an object to accelerate, decelerate or change direction.*

Force, mass and acceleration

If the net force increases, then **acceleration** will also increase. A motor bike can produce much more thrust force than a scooter, so its acceleration will be greater. Acceleration is directly proportional to the net force.

If the mass of an object is increased, then its acceleration will decrease. A scooter with a pillion passenger will not be able to drag off a scooter with a single rider. Acceleration is inversely proportional to mass.

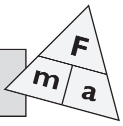
The relationship between acceleration, net force and mass is given by:

$$\textbf{Acceleration} = \frac{\textbf{net force}}{\textbf{mass}} \qquad \mathbf{a} = \frac{\mathbf{F}}{\mathbf{m}}$$

- This formula shows that if force increases then acceleration will increase, but if mass increases then acceleration will decrease.

Usually, the formula is expressed in this format:

Net force = mass x acceleration F = m x a



Note: mass must be in kg, acceleration in $m\ s^{-2}$ and force in N.

Weight and friction

In Science, **weight** is defined as the force of gravity (symbol **Fgravity** or **Fg**) pulling downwards on an object. Weight is measured in newtons and it is different from mass, which is measured in kilograms. Weight force can be found by modifying the above formula for force:

Weight = mass of object x **acceleration due to gravity**

On the surface of Earth the potential acceleration **g** of an object due to the force of gravity is about $10\ m\ s^{-2}$ (or $10\ N\ kg^{-1}$). All objects accelerate at $10\ m\ s^{-2}$ downwards if the effect of air friction is eliminated. The formula is:

Weight F_g = m x g = m x 10

- If your mass is 60 kg, then the weight force acting on your body is given by: **Fg = m** x **g =** 60 kg x $10\ m\ s^{-2}$ = 600 N

Friction or **drag** is a contact force that arises whenever a moving object rubs against another surface, which might be a solid, liquid or a gas.

As friction always opposes the motion of an object, it slows down an object and converts some of its kinetic energy into heat energy.

Friction can be unhelpful when it slows down cyclists, boats or planes, but it can also be useful for providing grip on the roads.

If a cyclist stops pedalling, then friction will slow the bike down. If sufficient force is applied to the pedals, the bike speeds up. But as speed increases so does the force of friction. Eventually friction will equal the maximum thrust of the cyclist, and the cyclist will not travel any faster.

If a force is applied to an object (**action force**), then the object will apply an equal but opposite **reaction force** to the object applying the force.

Momentum

Objects that are in motion possess something called **momentum**. Momentum is not a form of energy but rather a capacity to keep moving.

An object with lots of momentum is hard to stop. A cricket ball bowled by a fast bowler is much harder to stop than one from a slow bowler. So the faster an object travels the more momentum it has.

A cricket ball is harder to stop than a tennis ball thrown at the same speed. A cricket ball has more mass than a tennis ball. So the greater the mass of an object the more momentum it has.

The momentum an object has can be found using the formula:

Momentum = mass x speed = m x v

- The unit for momentum is $kg\ m\ s^{-1}$.

Activity 1 Modifying a Formula

Sometimes a formula may not be in the form you require.

Problem:
You are given an object's mass and the force applied and you have to find its acceleration. The formula provided is: **F = m** x **a**

☐ How do you rearrange this formula so that **a** is by itself?

☐ The *strategy* is to take the 'opposite action' and the *rule* is to do the same to both sides.

1 As **a** is multiplied by **m**, to get rid of **m** do the opposite – divide by **m**:

$$\frac{\mathbf{m \times a}}{\mathbf{m}}$$

2 But you must do the same to both sides: $\frac{\mathbf{F}}{\mathbf{m}} = \frac{\mathbf{m \times a}}{\mathbf{m}}$

3 Cancel to get rid of **m** on the right: $\frac{\mathbf{F}}{\mathbf{m}} = \frac{\cancel{\mathbf{m}} \times \mathbf{a}}{\cancel{\mathbf{m}}} = \mathbf{a}$

which is the same as: $\mathbf{a} = \frac{\mathbf{F}}{\mathbf{m}}$

Activity 2

1 Match up descriptions with terms.

a force	**A** the amount of matter in an object
b kinetic energy	**B** the unit used for force
c contact force	**C** something that can change the motion of an object
d non-contact force	**D** occurs when the net force on an object is not equal to zero
e mass	**E** the overall effect of combining the forces acting on an object
f kilogram	**F** the capacity of an object to keep moving
g magnitude	**G** the energy possessed by moving objects
h newton	**H** caused when an object passes through a body of water or air
i thrust	**I** a force that is applied to an object to make it move
j support	**J** the object applying the force must touch the other object
k net force	**K** caused by unbalanced forces acting on a free object
l balanced forces	**L** the force of gravity acting on an object
m unbalanced forces	**M** object applying force doesn't need to touch the other object
n acceleration	**N** the unit used for mass
o weight	**O** a force caused by surfaces rubbing against each other
p friction	**P** the size or strength of a quantity such as force
q drag	**Q** the force that a surface applies to an object resting on it
r momentum	**R** when two forces on an object are equal and opposite

2 Explain the difference between:

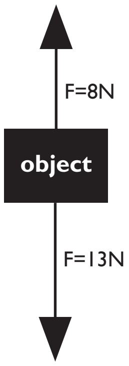
a contact and non-contact forces
b magnitude and direction of a force
c mass and weight
d balanced and unbalanced forces.

3 Describe the relation between the quantities below by using statements such as: 'If the net force on an object increases, then acceleration will . . . '

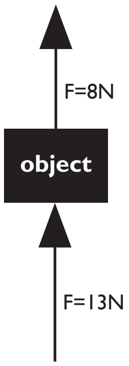
a net force on an object and its acceleration
b total mass of an object and its acceleration
c speed of an object and its momentum
d total mass of an object and its momentum.

4 For each of the diagrams below work out the net force acting on the object. State the magnitude and direction of the net force.

a



b



c

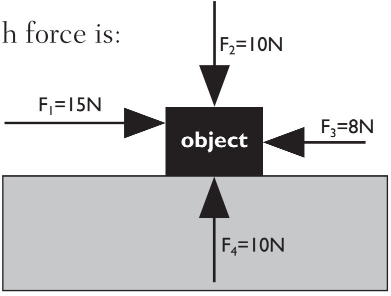
d

5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

a Pushes, pulls and twists are all forces.
b A force may change an object's speed or direction of motion.
c A force is always required to keep an object in motion.
d Most moving objects slow down because of friction.
e Forces transfer chemical energy to objects.
f Gravity is an example of a contact force.
g A force has magnitude and direction.
h Weight and support forces act in opposite directions.
i Unbalanced forces will cause a free object to accelerate only.
j Acceleration increases as net force increases, and decreases as mass increases.
k In Science, weight is measured in kilograms.
l Friction opposes the motion of an object.
m An object with a lot of momentum is hard to stop.

6 In the diagram of a free object, identify which force is:

a thrust
b weight
c friction
d support.



Answer the questions below.

e How can you distinguish between the thrust and the friction forces?

f What is the net force acting on the object in the vertical (up-and-down) plane?

g What change in motion will occur in the vertical plane?

h What is the net force acting in the horizontal (sideways) plane?

i What change in motion will occur in the horizontal plane?

j In which plane are forces balanced? Unbalanced?

k What effect do balanced forces have on a free object's motion?

l What effect can unbalanced forces have on a free object's motion?

7 After being hit, a ball with mass 0.20 kg flies through the air at a speed of 20 m s^{-1}.

a What is the formula for finding momentum?

b Calculate the momentum of the ball.

c The other player returns the ball at a speed of 10 m s^{-1}. What is the ball's momentum now?

d How much momentum would a bald ball of mass 0.18 kg travelling at 20 m s^{-1} have?

8 A group of students measured the acceleration of an empty trolley (mass 10 kg) as the net force applied to the trolley was increased in steps. The results are shown opposite.

Next, they used a constant net force on the trolley and measured the acceleration of the trolley as they increased the mass in the trolley in steps. These results are shown opposite.

a Describe the slope of the top graph line.

b What is the relationship between net force applied and the acceleration of the empty trolley?

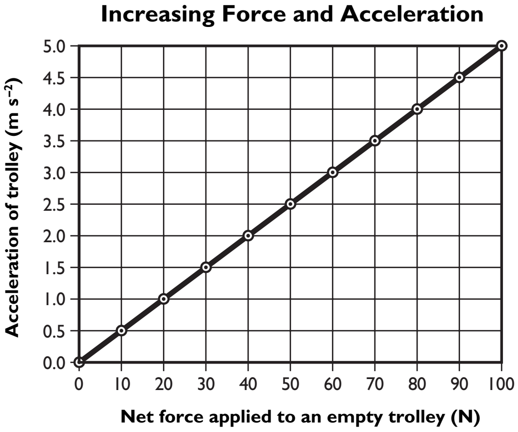
c If the net force doubles, what happens to the trolley's acceleration?

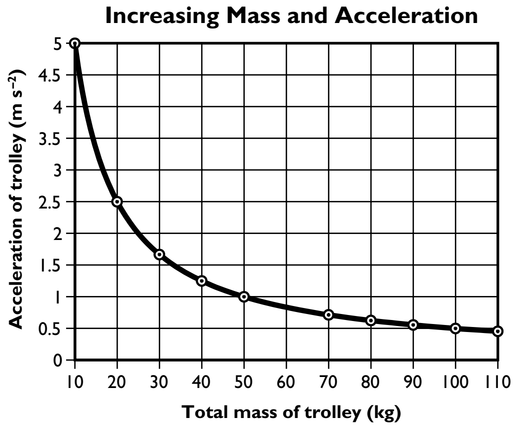
d Is acceleration directly or inversely proportional to net force?

e Describe the slope of the bottom graph line.

f What is the trolley's acceleration when its mass is 60 kg?

g What is the relationship between the total mass of the trolley and its acceleration when a constant force is applied?





h As the trolley's mass is doubled from 10 kg to 20 kg, what happens to the trolley's acceleration?

i Is acceleration directly or inversely proportional to total mass?

9 Read the passage below, then answer the questions that follow.

Bungee jumping

Bungee jumping is the sport of leaping off high places such as bridges with a rubber rope attached around your ankles. The rope stretches and contracts, eventually leaving the jumper dangling above the ground.

Bungee jumping originated in Pentecost Island, off the northeast coast of Australia, as an initiation rite. The islanders built very high platforms, attached vines to their ankles and leapt off. Commercial bungee jumping was initially developed in New Zealand.

Standing in a helicopter, the jumper has gravitational potential energy. The force of gravity is the cause of the weight force acting on the jumper. When the jumper leaps out, the weight force makes her accelerate downwards at close to 10 m s^{-2}. As she accelerates downwards, she gains kinetic energy.

As she falls the rubber rope extends to its normal length and is then stretched further by her weight. When rubber is stretched, an 'elastic force' is set up. This force increases rapidly as the rope stretches. When the elastic force becomes greater than the weight force, it slows the jumper down.

When the rope is at its maximum stretch, the jumper changes direction. The elastic force, now at its maximum, accelerates her upwards.

As she rebounds upward, the rope shortens and the elastic force weakens. When the elastic force becomes weaker than the weight force, the jumper slows down and eventually stops rising and begins to fall again.

a What type of energy does the jumper have while standing in the helicopter?

b When she leaps out, what is the unbalanced force acting on her?

c Weight force transforms her gravitational energy into what form of energy?

d Why does her acceleration downwards become less than 10 m s^{-2}?

e What force begins to oppose the weight force acting on her?

f How is the magnitude of the force in the rubber rope related to its extension?

g When the jumper's direction is changing, are the forces balanced?

h What is the pattern of energy conversion?

10 A cyclist was pedalling along at a constant speed on a level road.

a If the mass of the cyclist and his bike was 80 kg, what would the weight force be?

b What would the support force acting on the cycle and rider be? What direction would it act in?

c The forces acting on the bike are balanced. How do you know this?

d If the force of friction acting on the bike was 60 N, what thrust force must the cyclist be applying to the pedals?

The cyclist increases the thrust on the pedals, so that the net force acting on the bike is 160 N pushing him forward.

e Are balanced or unbalanced forces acting now? How do you know?

f Calculate the acceleration of the bike and rider.

As he approaches some traffic lights, he brakes and the bike decelerates at 1.5 m s^{-2}.

g What is the size and direction of the net force acting on the bike?

h When the bike is stationary, what would be the magnitude and direction of the weight, support, thrust and friction forces?

11 Study each photograph below and discuss the desirable and an undesirable effects of friction in each situation. Consider the different surfaces rubbing against each other.

Unit 23

Energy, Work And Power

Learning outcomes

On completing this unit you should be able to:

- ❑ Define work and relate it to force and energy
- ❑ Use the formula: **Work done = force x distance**
- ❑ Calculate the kinetic or potential energy gained when work is done
- ❑ Define power and use the formula: **Power = work done ÷ time**
- ❑ Identify the type of relationship that exists between two variables

Energy and work

In an earlier unit, **energy** was defined as the capacity to do work – an object has energy if it is capable of doing work. But what is work?

Work is done when a force moves an object. When you lift a box, you do work. When you push a trolley along, you do work. If you apply a force to a trolley and it does not move, no work is done.

When a **force** is applied to an object and it moves, then the object gains energy. This energy may be potential energy if the object is lifted, or kinetic energy if the speed of the object increases. The object being moved will gain the energy that the object causing the force loses. Remember the Law of Conservation of Energy! (Some energy will be lost as heat though.)

Work involves a transfer of energy, which occurs when a force moves an object. Work, symbol **W**, is measured in joules, the unit for energy.

One **joule** is the amount of work done when a one newton force moves an object one metre in the absence of friction.

If a force moves an object, work is done and the object gains energy.

Calculating work done

If you apply a large force to push a trolley along, you do more work than when you use a small force. The greater the force, the more work is done.

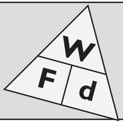
If you push the shopping trolley around all the aisles, you do more work than if you had just pushed it along one aisle. The further an object is moved, the more work is done.

The amount of work done is proportional to both the size of the force used and the distance the object is moved.

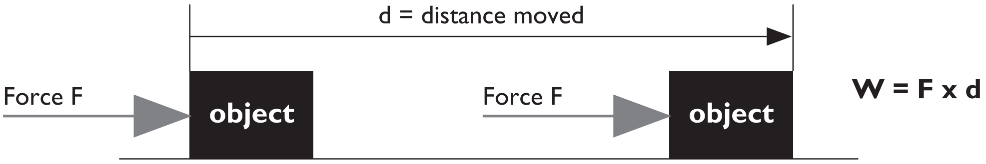
Work can be calculated using this formula:

Work done = force applied x distance moved

$W = F \times d$



☐ Note: force must be in newtons, distance in metres to give work in joules.



Kinetic energy gain

If a stationary object is made to move horizontally by a force, then work has been done to the object and it gains energy.

The type of energy this object gains is **kinetic energy**, symbol **EK**. As it moves, some of that kinetic energy will be transformed into heat energy due to friction.

The gain in kinetic and heat energy is equal to the work done by the force, so:

Gain in kinetic energy + gain in heat energy = work done by the force

If there was no friction, then:

Gain in kinetic energy = work done by the force
= force used x distance moved

$$E_K = F \times d$$

More work must be done to move a full trolley at the same speed as an empty one. If more work is done to the heavier trolley, it must gain more kinetic energy. *Kinetic* energy is proportional to the object's mass.

For a cyclist to double his speed, four times as much work must be done. When speed is doubled, $\mathbf{E_K}$ increases four times. Kinetic energy is proportional to the square of an object's speed.

$\mathbf{E_K}$ can be found using this formula:

$\mathbf{E_K = \frac{1}{2} mv^2}$ mass in kg, speed in m s^{-1}

Potential energy gain

When you lift a bag higher, you do work – you apply a force to the bag and it moves. If you have done work to the bag, then it must have gained energy.

The type of energy that a lifted object gains is called **gravitational potential energy**, symbol $\mathbf{E_P}$. The gain in potential energy is equal to the amount of work done in lifting.

Gain in potential energy = work done $\mathbf{E_P = W}$

The amount of work done in lifting is given by the formula:

Work done = lifting force x distance lifted $\mathbf{W = F \times d}$

The force needed to lift an object at a constant speed is the same size as the **weight force** acting on the object. So the lifting force is given by:

Lifting force = weight force F_g **$F = F_g = m \times g$**

where **m** is the object's mass and **g** is the acceleration due to gravity.

Putting these formulae together gives:

Gain in Potential Energy
= work done lifting **$E_P = W$**
= lifting force x distance lifted **$E_P = F \times d$**
= weight force x distance lifted **$E_P = F_g \times d$**
= mass of object x g x distance lifted **$E_P = m \times g \times d$**

Gain in Potential Energy $E_P = m \times g \times d$

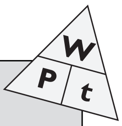
If the height lifted is given the symbol **h**, then the formula is **$E_P = mgh$**.

Power and work

If you climbed a vertical pole, you would do work. The amount of work done depends on the force you apply to lift your body and the height you climb. You could climb the pole slowly or more quickly, but you would still do the same amount of work.

To climb the pole quickly you must increase your power. **Power**, symbol **P**, *is the rate at which work is done*. (**Rate** means how fast something occurs.) If the work is done rapidly, then your power output will be high. Conversely, if the same amount of work is done slowly, then your power will be low.

The formula used to calculate power is:



$$\textbf{Power} = \frac{\textbf{work done}}{\textbf{time taken}} \qquad P = \frac{W}{t}$$

As work done is measured in joules and time in seconds, the unit for power is joules per second or **watts**. One watt of power means one joule of work is being done each second.

As work done increases, so does power – power is proportional to work. As the time taken increases, power decreases – power is inversely proportional to the time taken.

The work done **(W)** to an object equals the total energy **(E)** it gains, so the above formula can be written as: **$P = E/t$** and then rearranged as **$E = Pt$**

Activity 1 Spotting relationships

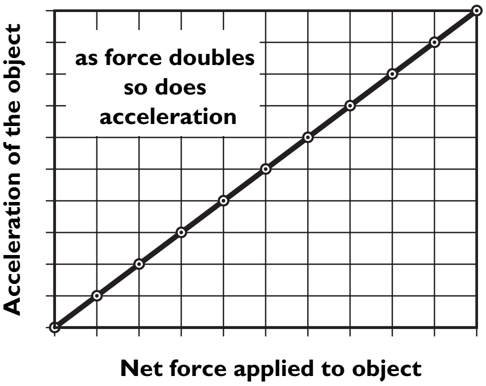
Two **variables** or **quantities** may be related, but how?

Usually a change in one variable causes a change in the other. The variable you alter is the **independent variable** and the variable that changes as a result is the **dependent** one.

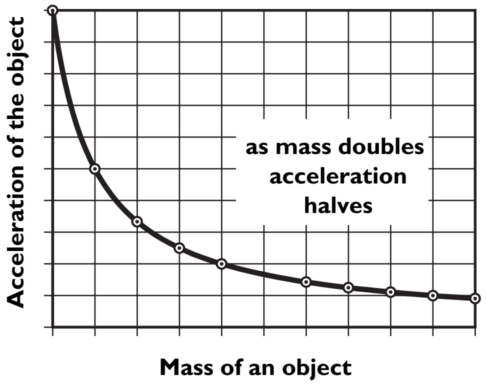
You can identify the type of relationship from a graph.

As the independent variable *increases*, the dependent variable may:

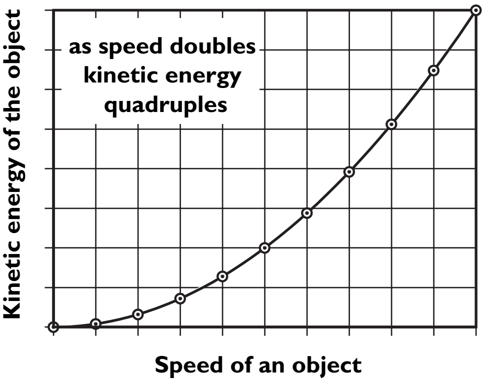
a *rise evenly* – the dependent variable is proportional to the independent variable



b *drop rapidly* – the dependent variable is inversely proportional to the independent one



c *rise rapidly* – the dependent variable is proportional to the square of the independent variable.



Activity 2

1 Match up descriptions with terms.

a energy	**A** something that is done when a force moves an object
b force	**B** the acceleration that the force of gravity will cause
c work	**C** how fast something is done
d a joule	**D** doubling one variable causes the other to double as well
e kinetic energy	**E** something that varies in magnitude (size)
f gravitational energy	**F** one joule of work being done each second
g weight force	**G** the energy possessed by a moving object
h g	**H** property of objects which can be measured or calculated
i power	**I** doubling one variable causes the other to be halved
j rate	**J** having the capacity to do work
k a watt	**K** variable that causes a change in another variable
l proportional	**L** the force of gravity acting on an object
m inversely proportional	**M** needed to change the motion of an object
n variable	**N** work done when a 1 N force moves an object 1 m
o quantity	**O** variable increases in proportion to the square of the other
p independent variable	**P** a variable that alters because of a change in another
q dependent variable	**Q** the rate at which work is done
r proportional to square	**R** type of energy an object gains when lifted

2 Explain the difference between:

a energy and work

b kinetic and gravitational energy

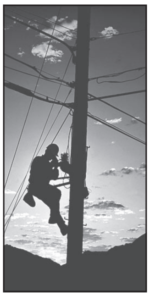
c work and power

d independent and dependent variables.

3 Study each of the photos and the captions below and decide whether work is being done or not. (Give a reason for your decision.)

A cyclist cruises along the road

A tug is unable to move the ship



A linesman is climbing the pole

4 Use the formula for work on page 162 to solve these problems.

- **a** A cyclist applies a constant thrust force of 80 N to the pedals and travels along a level road for 2 km. How much work is done?
- **b** A linesman climbs 9 m up a pole at a steady speed. If the force he uses to lift his body is 960 N, how much work does he do?

5 Decide whether the following statements are true or false. Rewrite the false ones to make them correct.

- **a** To be able to do work you must possess energy.
- **b** If you push on a car but cannot move it, you are still doing work.
- **c** When work is done to an object it gains energy.
- **d** The amount of work done depends on the size of the force used only.
- **e** If an object is made to move horizontally, it will gain kinetic energy.
- **f** The speed of a moving object affects its kinetic energy more than its mass does.
- **g** The force needed to lift an object at a constant speed is the same size as the weight force acting on it.
- **h** The amount of work done in climbing a ladder does depend on how long you take.
- **i** If your power output is high you will be doing work rapidly.
- **j** The dependent variable will alter when you change the independent variable.
- **k** Rate is how fast something is done.

6 Describe the relation between quantities using statements such as: *'If the force used is increased, then the work done will . . .'* (Choose from: increase/increase rapidly/fall rapidly/be unchanged.)

- **a** force used and work done (assume object moves a set distance)
- **b** distance moved and work done (assume a constant force is used)
- **c** mass of object and kinetic energy (assume speed is constant)
- **d** speed of object and kinetic energy (assume mass is constant)
- **e** height lifted and potential energy (assume mass is constant)
- **f** time taken to do work and power (assume work done is constant).

7 The questions below relate to the photographs.

A 5 kg shopping bag is lifted 1 m

A trolley is pushed 15 m by a force of 12N

- **a** Is work being done to the bag? How do you know?
- **b** How much work will be done lifting the bag?
- **c** What type of energy will the bag gain?
- **d** How much energy will the bag gain?
- **e** Is work being done to the trolley? How do you know?
- **f** How much work is done to the trolley?

g What type of energy will the trolley gain?

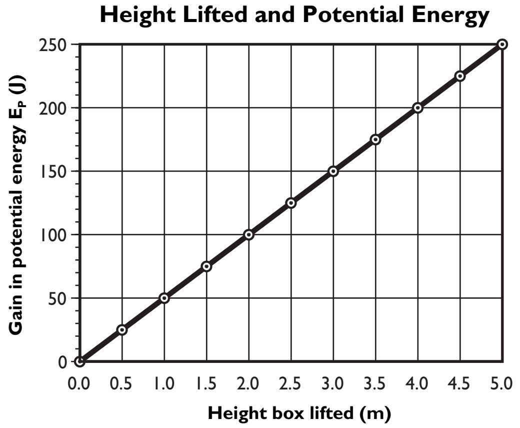
h How much energy will the trolley gain?

8 In this first graph, the energy gained by a box was plotted against height lifted.

a Describe the slope.

b What relationship exists between height and energy?

c In what way is gain in energy proportional to height?

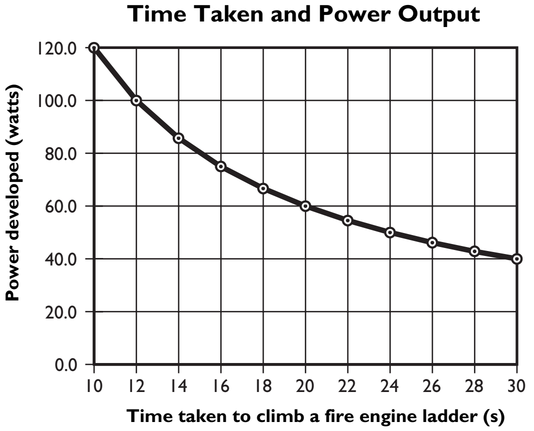


In this second graph, the power of a firefighter was plotted against time taken to climb a ladder.

d Describe the slope.

e What relationship exists between power and time?

f In what way is power proportional to climbing time?

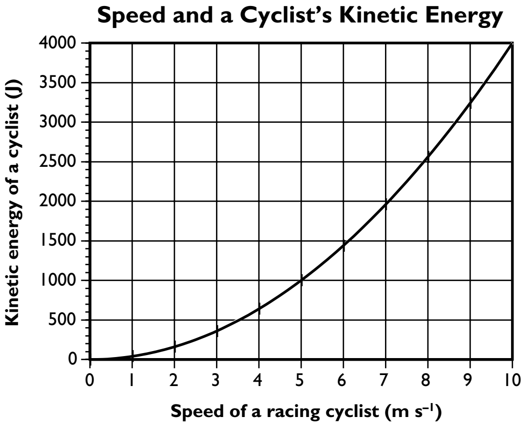


In this third graph, the kinetic energy of a cyclist was plotted against his speed.

g Describe the slope.

h What relationship exists between kinetic energy and speed?

i In what way is the cyclist's kinetic energy proportional to speed?



9 Read the passage below, then answer the questions that follow.

Stopping a speeding car

Imagine you are driving a car along a road and a dog starts to cross in front of you. Will you be able to stop before you hit the animal? The total distance you travel before you halt depends on your reaction distance and the car's braking distance. The total distance is the sum of the two.

The distance you travel before the brakes engage depends on the time it takes for you to react to the danger and the speed you are travelling at. The average reaction time is about two seconds. The faster your speed, the greater the

reaction distance travelled before the car starts slowing. The average reaction distance in metres can be found by multiplying speed in kilometres/hour by 0.56.

A speeding car has kinetic energy. For your car to stop, it must lose its kinetic energy through the action of a force in the direction opposite to your motion. This force is supplied by the brakes. As the brakes are applied, the car's kinetic energy is changed into heat energy due to friction. The brakes and tyres heat up.

As the car slows, more and more kinetic energy is transformed into heat until the car finally loses all of its kinetic energy and you stop.

The amount of kinetic energy your car has to start with is proportional to the square of your speed. If you double your speed, the car's kinetic energy will increase by four times. As a consequence, if you double your speed your braking distance will quadruple.

a What is total stopping distance made up of?
b What is meant by reaction time?
c What two factors will your reaction distance depend on?
d At 100 km hr^{-1} what is the average reaction distance?
e What must happen for your car to lose kinetic energy?
f What happens to your car's kinetic energy when the brakes are applied?
g What other factors affect braking distance?
h Why will braking distance be quadrupled if you double your speed?
i If your braking distance at 50 km hr^{-1} is 15 m, what will it be at 100 km hr^{-1}?

10 The distance a car travelled after the brakes were fully applied was measured for different speeds.

Speed (km hr^{-1})	**Braking Distance (m)**	**Kinetic Energy (kJ)**
0	0	0
10	0.5	40
20	2	160
30	5	360
40	8	640
50	14	1000
60	20	1440
70	28	1960
80	32	2560
90	44	3240
100	56	4000

a Plot a graph of braking distance versus speed. Make sure speed is on the horizontal axis.

b Identify which variable is the independent one and which is the dependent variable.

c Describe the slope of your graph.

d As the speed of the car increases what happens to the braking distance?

e In what way is braking distance proportional to the speed of the car?

The kinetic energy of the car was calculated for the different speeds and recorded in the third column of the table.

f Plot another graph showing kinetic energy versus speed. Make sure speed is on the horizontal axis.

g Why should speed be placed on the horizontal axis?

h Describe the slope of this graph.

i As the speed of the car increases, what happens to the car's kinetic energy?

j In what way is kinetic energy proportional to the car's speed?

k How do the shapes of the two graphs compare?

l Make a statement summarising the effect of speed on kinetic energy and braking distance.

Unit 24

Waves

Learning outcomes

On completing this unit you should be able to:

- ☐ Explain the nature and properties of waves
- ☐ Use measurements of wave properties in calculations

What are waves

Waves are **vibrations** (or **oscillations**) moving through something – a **medium.** As a wave passes, each bit of the medium **vibrates in turn**. The vibrations appear to move through the medium. Each bit of the medium in turn waggles/vibrates/oscillates, but stays where it is. It doesn't move with the wave. Think of a Mexican wave in a football crowd. The wave moves round the ground, but each spectator stays in their seat, vibrating (standing up then sitting down) when it's their turn.

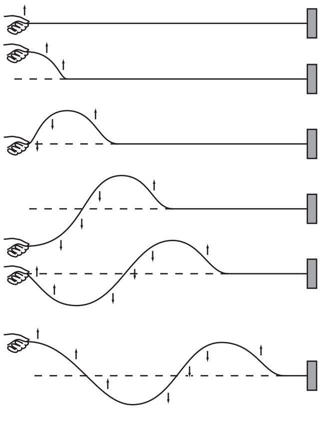


Figure 24.1 Transverse waves

Waves **transfer energy** as they move. Light, sound, water waves, seismic waves (earthquakes), radio waves, X-rays and gamma rays are all examples of waves. The medium can be **matter** (real stuff – solid, liquid, gas). Sound waves, water waves and seismic waves need matter to travel through.

Some waves don't need matter to pass through. This is the case for **electromagnetic waves** (radio, microwaves, infra-red, light, ultra-violet, X-rays, gamma rays). What vibrates is an electrical or magnetic field. These waves can therefore travel through a **vacuum.** Space is almost a perfect vacuum. Light waves from the sun can travel through the vacuum of space to Earth.

When waves meet a boundary, where the medium changes, they may:

a **reflect** – bounce back, e.g. light at a mirror, sound echoing off a wall

b **refract** – go through the boundary, usually changing **speed** and **direction** as they do, e.g. light through spectacles, water waves going from deep to shallow water

c get **absorbed** – give up their **energy**, warming up the surface layer, e.g. in a solar heating panel.

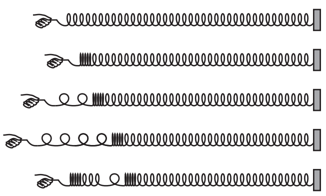


Figure 24.2 Longitudinal waves

Types of waves

Transverse waves vibrate at **right angles** to the direction of the wave. The word transverse means **across**. Examples of transverse waves are all electromagnetic waves (light, etc), waves on the surface of water, some seismic waves – S (shear or shake) waves.

Longitudinal waves vibrate **along the same direction** as the waves. The word **longitudinal** means **along**. Examples of longitudinal waves are sound waves, waves in a stretched spring, some seismic waves – P (push or pressure) waves.

Measuring waves

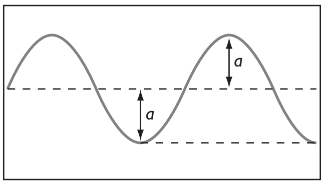


Figure 24.3 Amplitude

The **amplitude** (**a**) is the total distance between the crest (top) of a wave and the centre line. Because it is a distance it can be measured in metres, centimetres, millimetres or smaller units of length.

The **wavelength** is the distance between one crest of the wave and the next crest. It is also a distance so can be measured in metres, centimetres etc. It is sometimes given the Greek letter λ (lambda). It's also the distance between one part of the wave and the next part that is at exactly the same stage of vibration – but 'crest-to-crest' is easier to remember.

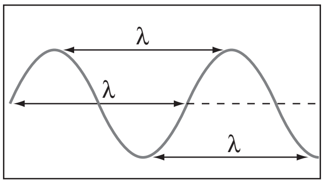


Figure 24.4 Wavelength

The **frequency** (**f**) is the number of complete waves passing a point each second. It is a 'number per second' so it is measured in **/s** or $\mathbf{s^{-1}}$; usually called **hertz** (**Hz**) after a German physicist.

1 kilohertz = 1 kHz = 1000 Hz

1 megahertz = 1 MHz = 1 000 000 Hz

☐ For example: 100 complete sound waves enter your ear in a second (you'd hear a deep hum).

f = 100 per second
= 100 /s
= 100 s^{-1}
= 100Hz

The **speed** of a wave (**v**) is a measure of the speed at which the vibrations in the wave move from one point to the next. Wave speed is measured in metres per second (m s^{-1}).

☐ For example: speed of sound in air = 330 m s^{-1}
speed of light in space = 300 000 000 m s^{-1}

A sound is produced by a vibrating object (guitar string, drum skin, voice box in throat). It travels through the air as a wave vibrating the air molecules. The bigger the amplitude of a sound wave, the louder the sound. The higher the frequency of a sound wave, the higher the **pitch**. The human ear can hear sounds ranging from 20 Hz to 20 000 Hz. Sounds over 20 000 Hz are called ultrasonic. Thunder has a low pitch with a frequency less than 50 Hz. A whistle has a high pitch with a frequency close to 1000 Hz.

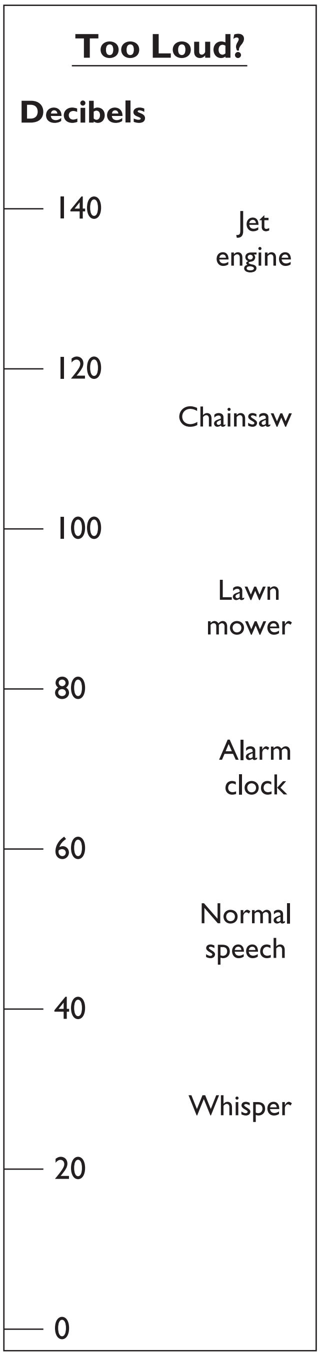


Figure 24.5 Decibel levels

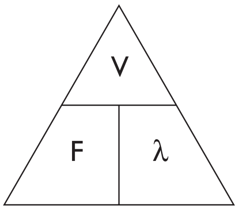
How fast do waves travel?

The general rule is:

speed of wave = number of waves per second x length of waves

speed = frequency x wavelength

$v = f\lambda$



The triangle method can be used for remembering this formulae. Cover up the variable that you are trying to find to give the equation to use.

$$\mathbf{v = f \times \lambda} \qquad \mathbf{f = \frac{v}{\lambda}} \qquad \mathbf{\lambda = \frac{v}{f}}$$

Activity 1

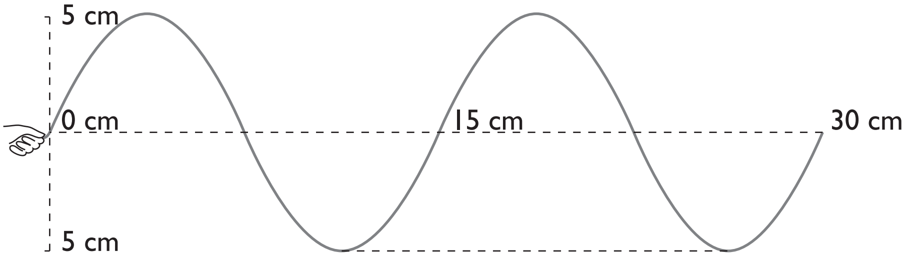
1 Complete the paragraph using the words below.

electromagnetic	energy	medium
longitudinal	sound	transverse

Waves are vibrations moving through a (**a**) __________. Most waves need matter to travel through. (**b**) __________ waves can travel through a vacuum. All waves transfer (**c**) __________ as they move. In (**d**) __________ waves, such as (**e**)__________, vibrations are along the waves' direction. In (**f**) __________ waves, such as light, the vibrations are at right angles to the waves' direction.

2 In the following diagram the wave has moved for two seconds.

Use the picture to answer the following questions.



a What is the number of complete waves in the diagram?

b What is the amplitude of the waves?

c What is the wavelength?

d How many waves are generated in two seconds?

e What is the frequency of the waves?

3 Fill in the gaps in this table of typical waves.

Type Of Wave	**Frequency**	**Wavelength**	**Speed**
Water ripple	12 Hz	3 cm	**a** ?
Sound in air (bass guitar)	220 Hz	1.5 m	**b** ?
Sound in air (whistle)	**c** ?	0.1 cm	330 m/s
Sound in water (whale)	50 Hz	**d** ?	1500 m/s
Radio	100 Mhz (100 million Hz)	**e** ?	3 x 10^8 m/s (300 million m/s)

4 One hundred complete water waves pass a point every 5 seconds. Their wavelength is 4 cm. What is the frequency of the waves?

5 A radio station produces radio waves of frequency 200 000 Hz and a wavelength of 1500 metres.

a What is the speed of sound waves?

b Another station produces waves at 500 kHz. What is their wavelength?

6 **a** Give one example of a transverse wave.

b Give one example of a longitudinal wave.

c What is the distance between two adjacent crests on a water wave called?

d Which type of wave travels through the air as a vibration of the air molecules?

e If the amplitude of a sound wave increases, what happens to the sound?

f If the frequency of a sound wave increases, what happens to the sound?

g What is the name for very high frequency sounds waves used to 'see' babies before they are born?

7 Sound travels at 330 m s^{-1}.

a If you fire a gun at a high wall 110 metres away, how long will it take the echo to reach you?

b What is the wavelength of the note from

i a deep organ pipe (20 Hz)?
ii the top note on a piano (2 kHz)?

Answers

Unit 1: Co-ordinating The Body

1 **a** sensory **b** sensory neurone **c** transmitter
d motor neurone **e** effector organ

2 **a** an automatic response **b** the ear **c** a gland
d a synapse

3

Nervous system	**Endocrine system**
The message travels as an electric current (impulse)	The message travels in the form of a chemical (hormone)
The message travels along a neurone	The message travels in the blood
This system regulates longer lasting processes in the body	A hormone can affect many cells in the body
Usually affects only one muscle or gland	Blood sugar level is controlled by this system
This system controls short lasting actions	Growth is controlled by this system
Sneezing is activated by this system	
Vomiting is activated by this system	

4 **a** the adrenal glands **b** endocrine glands
c the liver **d** the 'fight or flight' reaction
e regulate salt balance in the body **f** the pituitary
g oestrogen **h** switch the secretion of a hormone on
i testosterone **j** the pancreas

5 **a** special proteins bind to hormones acting as carriers that control the amount of hormone that is available to affect the target cells

b it locks on to the cells receptors, which send chemical instructions into the cell

c a pituitary hormone that stimulates the thyroid gland to produce thyroid hormones

d the negative feedback system turns off the production of a hormone by a gland when enough has been made

Unit 2: Maintaining The Body

1 **a** G **b** A **c** E **d** F
e B **f** I **g** J **h** H
i D **j** C

2 **a** thermoregulating **b** lower **c** homeostasis
d shivering **e** raised

3 **a** homeostasis **b** thermoregulation **c** insulin
d respiration **e** water

4 An increase in body temperature is detected by a part of the brain called the hypothalamus. Messages are sent to the sweat glands telling them to secrete sweat. When the sweat evaporates, it takes heat from the skin. Your blood vessels (veins) also dilate (get bigger). This means that blood carries more heat into the skin, the heat is lost to the air and you cool down.

5 **a** Antibiotics kill bacteria by interrupting the machinery that makes the bacterial cell walls.

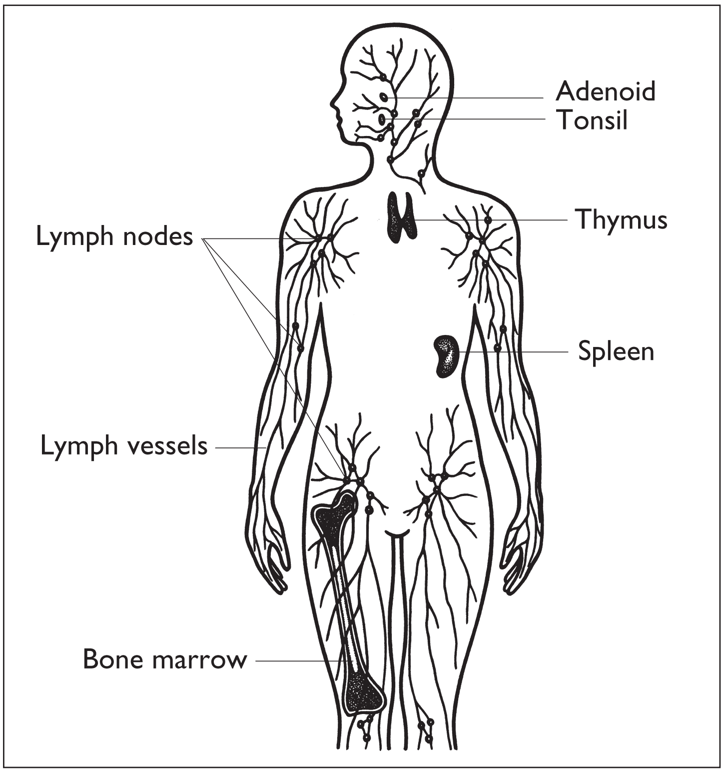
b Human cells are not usually affected by antibiotics because they do not have cell walls.

c Antibiotics do not work on viruses because they are not alive

d Some bacteria are not affected by an antibiotic because of their genetic makeup. They will reproduce and all their offspring will also not be affected by the antibiotic.

6 e, a, f, d, b, c.

7



Unit 3: Plant And Animal Cells

1 **a** 9 **b** 1 **c** 11 **d** 12
e 3 **f** 10 **g** 6 **h** 2

i 7	**j** 8	**k** 13	**l** 4	**m** 5

2 f, h, a, e, c, d, g, b

3 **a** A depression slide is used when you want to see a small living organism in a drop of water.

b A cover slip is used to flatten out a liquid drop so that less focusing is required. It also protects the lens of the objective lens from getting wet.

c It is very easy to push the high power objective lens on to the slide. This could cause the lens to get wet or break the slide.

d The slide will dry out.

e The cover slip will float away on the liquid.

f A stain helps certain parts of cells to be seen more clearly under the microscope.

4 Slide A shows plant cells and Slide B shows animal cells. Plant cells have a regular shape because of their cell wall and are larger because of their vacuoles. Animal cells are smaller and have irregular shapes.

Unit 4: Chromosomes, Genes And DNA

1

a K	**b** O	**c** G	**d** Q
e C	**f** M	**g** F	**h** J
i D	**j** N	**k** A	**l** P
m E	**n** L	**o** H	**p** B
q I			

2 **a** a gene is an inherited object that determines the appearance of a trait/ the genome is the total collection of genes that an organism possesses

b identical chromosomes are ones produced by DNA self-replication/ homologous chromosomes are similar in size and appearance but each one comes from a different gamete

c all cells except for gametes are body cells and they have the same number of chromosomes as the zygote/gametes are egg and sperm and they have half the normal number of chromosomes

d mitosis is a type of cell division that produces two cells and each cell has the same set of chromosomes as the original cell/meiosis is a type of cell division that produces four gametes (egg or sperm), each of which has only half the normal number of chromosomes

3

	Number of Chromosomes in . . .			
Species	**Egg**	**Sperm**	**Zygote**	**Body Cell**
humans	23	23	46	46
chimps	24	24	48	48
horses	32	32	64	64
dogs	39	39	78	78
cats	19	19	38	38

a meiosis

b fertilisation

c mitosis

4 **a** true **b** true
c false – different species can have different numbers of chromosomes
d true **e** true
f true **g** true
h true **i** true
j false – meiosis produces four gametes with half the normal number of chromosomes

5 **a** human – because there are 46 chromosomes visible
b so that in mitosis two cells are produced, each with the same set of chromosomes as the original cell
c 92 **d** DNA self-replication
e 46

6 **a** 23
b length of chromosome and where duplicates are attached to each other
c homologous chromosomes
d one from an egg and the other from a sperm
e two in the bottom right corner are different sizes/they are the sex chromosomes X and Y, which produce a male

7 **a** original cell **b** chromosomes
c chromosome duplicates **d** spindle
e two new cells **f** mitosis
g two cells produced each with same number of chromosomes as the original cell
h chromosomes have been duplicated
i chromosomes become attached to the spindle and duplicated chromosomes are separated
j both cells have two chromosomes and those chromosomes are identical to the ones in the original cell

8 **a** original cell **b** pair of homologous chromosomes
c spindle **d** pair of duplicated chromosomes
e gametes **f** meiosis
g because four cells are formed and each of them has half the number of chromosomes as the original cell
h testicles in males and ovaries in females
i chromosomes have been duplicated
j they are separating **k** homologous pairs
l duplicated pairs
m the four cells have half the number of chromosomes as the original cell and the set of chromosomes in each differs
n sperm

9 **a** to identify the location of the 30 000 genes that make up the human genome/to determine the entire sequence of bases that make up human DNA
b 1304 genes per chromosome on average (30 000 ÷ 23)
c 130 million bases per chromosome on average (3 000 000 000 ÷ 23)
d base units C, G, A and T
e because samples have come from different people
f 99.9%
g first they work out what the DNA sequence should be from the protein, then they analyse each chromosome until they find the one with that DNA sequence
h June 2000

10 **a** GGC TAG CTA AGC TG
b CCG ATC GAT TCG AC
c two strands are unzipping towards the left
d new strands are being built on to the old strands, towards the left
e C is an anti-code strand and D is a code strand
f Cs only fit with G bases and Ts will only fit with A bases
g two chromosomes that are identical/duplicated chromosomes

Unit 5: Applied Genetics

1 **a** G **b** J **c** Q **d** E
e B **f** M **g** A **h** R
i D **j** N **k** C **l** I
m P **n** F **o** O **p** H
q L **r** K

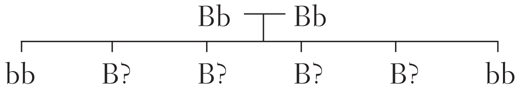
2 **a** a trait is a feature of an organism whose appearance is determined by genes/a gene is an inherited object that affects the appearance of a trait
b phenotype is the appearance of an organism for a particular trait/genotype is the two genes an organism possesses for a trait
c in a homozygous genotype the two genes are the same allele/in a heterozygous genotype the two genes are different alleles
d a dominant gene is one that will always be expressed if present/a recessive gene is one that will only be expressed if you have two of them (i.e. if the dominant gene is absent)

3 **a** both have straight-haired phenotypes
b both will have genotypes cc
c both are homozygous
d the mother will have a c in her genotype
e she could be either straight-haired or curly as in both cases she would be able to pass on a single straight-haired gene to her son

4 **a** mother's phenotype is non-roller and daughter's phenotype is roller
b mother's genotype would be rr and daughter's phenotype would be Rr
c mother only
d the father must have had an R in his genotype but he could be either RR or Rr/his phenotype would be roller in either case

5 **a** false – gametes have one gene per trait and organisms have two
b true **c** true
d false – organisms usually have two genes in their genotype for a trait
e false – in a heterozygous genotype the two genes are different
f true **g** true
h true **i** true
j true

6 **a** homozygous
b white rabbit has genotype bb and the brown rabbit has the genotype BB
c all Bb
d



7 **a** phenotype chances: 100% black
b phenotype chances: 50% black and 50% brown
c Angus and Pesky, as neither produced any brown offspring in their litters
d Mac and Rastus, because some of their offspring were brown indicating they had a hidden gene for brown fur – which means they must be heterozygous
e Mac and Rastus
f Mac and Rastus
g test crosses are used to uncover any hidden recessive genes – the test cross animal will have a homozygous recessive genotype

8 **a** we are the only species with a consistent bias to one particular side of the body i.e. the right hand
b able to use either hand with equal ease
c left-handedness does run in families
d two left-handed parents produce both right- and left-handed children/ identical twins do not necessarily have the same handedness
e R+R+ or R+R-
f right-handed
g you can be either left, right or ambidextrous

9

Parents	Offspring Genotypes	Offspring Phenotypes
CC x CC	CC = 100% Cc = 0% cc = 0%	curly = 100% straight = 0%
CC x cc	CC = 0% Cc = 100% cc = 0%	curly = 100% straight = 0%
CC x Cc	CC = 50% Cc = 50% cc = 0%	curly = 100% straight = 0%
Cc x Cc	CC = 25% Cc = 50% cc = 25%	curly = 75% straight = 25%
Cc x cc	CC = 0% Cc = 50% cc = 50%	curly = 50% straight = 50%
cc x cc	CC = 0% Cc = 0% cc = 100%	curly = 0% straight =100%

a CC x CC **b** cc x cc
c CC x CC, CC x cc, CC x Cc and cc x cc
d only Cc x Cc
e both curly-haired parents could have a hidden straight-haired gene to produce a child with straight-hair, but two straight-haired parents cannot possibly have any curly-haired genes

Unit 6: Bacteria, Fungi And Viruses

1 **a** Q **b** K **c** B **d** H
e M **f** F **g** J **h** O
i D **j** P **k** C **l** L
m E **n** A **o** G **p** I
q N

2 A – bacteria, B – fungi, C – viruses

3 **a** genes **b** protein coat **c** cell wall
d cell membrane **e** flagellum **f** chromosome
g cytoplasm **h** spore case **i** spores
j hyphae **k** bacterium and fungus **l** reproduction
m usually only visible under the microscope

4 **a** false – some micro-organisms can be seen without the aid of a microscope
b true **c** false – viruses are non-living
d true **e** true
f true **g** true
h false – spores are usually a form of asexual reproduction
i true **j** true

5 **a** consumers/enzymes/parasites/pathogens
b immobile/food/saprophytes/digest
c reproduce/cells/pathogens

6 **a** duplication of chromosome **b** pinching off of parent cell
c separation of daughter cells **d** binary fission
e asexual **f** very rapid
g all offspring are genetically identical

7 **a** attachment of virus to host cell
b insertion of genes **c** replication of virus
d bursting of cell to release new viruses
e replication **f** no
g they make the cells produce multiple copies of the virus
h by mutations of their genes
i because they always damage the host cell

8 **a** release of spores **b** dispersal of spores
c germination of spores
d very light for dispersal in air/resistant to survive difficult conditions
e float in the air/wind
f remain dormant or germinate if suitable conditions occur
g asexual

9 **a** Fungi are immobile like plants, but cannot make their own food as plants do. Fungi are not producers, they are consumers like animals in that they eat other organisms. But unlike animals they digest food outside of their bodies.
b Viruses are not considered to be alive as they are not made of cells, nor do they carry out any of the life functions other than reproduction. Even then, they have to use living cells to reproduce.
c Bacteria are consumers and digest their food outside of their bodies. Parasitic bacteria live in or on larger organisms, either feeding on them or on their food. Pathogenic bacteria feed off other organisms, causing disease by damaging tissue or by producing toxins. Saprophytic bacteria break down the bodies of dead organisms for food.

10 **a** unicellular organisms consist of a single cell only/multicellular organisms are made of many cells
b internal digestion occurs when animals eat food and break it down inside their bodies using digestive enzymes/external digestion occurs when bacteria and fungi release digestive enzymes on to food outside of their bodies and then absorb the broken down food
c inoculation is when micro-organisms or spores are introduced onto agar in order to culture them/incubation is when micro-organisms are grown on agar in warm conditions

11 **a** the spread of an infectious disease over a wide area
b easily passed from person to person through the air/so many people travel to other countries
c sore throat, fever, headache

d it came from another species
e handling of chickens or poultry
f takes over the cell and makes it produce multiple copies of the virus
g because a high proportion of the people infected died
h no evidence of person-to-person transfer of the disease
i weakened strain of the virus is injected into a person to produce resistance to the actual virus

12 a binary fission **b** doubles
c have identical genes **d** upward-curving line
e no
f shortage of space or food or moisture/poisoned by toxins produced by the bacteria themselves
g curve would turn the other way and level off
h by absorbing food from the contents of the human gut

Unit 7: Helpful Or Harmful?

1 a D **b** H **c** K **d** B
e J **f** C **g** M **h** O
i F **j** I **k** E **l** P
m G **n** Q **o** N **p** L
q A

2

viruses	❑ cause diseases	❑ control pests
bacteria	❑ cause diseases, rot food	❑ make yoghurt, cheese, insulin
fungi	❑ cause diseases, rot food	❑ make alcohol and antibiotics

3 a bacteria and fungi **b** yeast fungi
c yoghurt bacteria **d** yeast fungi

4 a true **b** false – bacteria in gut not fungi
c true **d** false – bacterial infections only
e true
f false – not all diseases are caused by pathogens
g true **h** true
i true

5 a biotechnology involves the use of micro-organisms for the benefit of humans/biological control involves the use of predators, parasites or pathogens to control pests
b an antigen is a marker chemical on a pathogen/an antibody is a chemical produced by the body's defence system that attacks a pathogen
c a disinfectant is a strong chemical used to kill micro-organisms around the house/an antiseptic is a milder chemical applied to cuts and wounds to prevent infections
d immunity is the body's ability to prevent an infection by a particular pathogen occurring/vaccination is an injection of dead or weakened micro-organisms to produce artificial immunity to the real pathogen

6 a cells/pathogens/engulf/antibodies/antigens
b pathogen/immunity/antibody/artificial/vaccinated/blood
c fungi/bacteria/resistance

7 a used to kill micro-organisms around the house
b whether the disinfectant kills the bacteria growing around it
c has no living micro-organisms/so that results are not affected by the presence of other micro-organisms

d so that the same bacteria grow all over the plate
e inoculation is introducing micro-organisms onto a medium/incubation is growing micro-organisms in a warm place
f to fairly compare the effectiveness of different disinfectants
g absorb the disinfectant
h pale yellow – bacterial growth/clear areas – no bacteria
i A – because it has the largest surrounding area with no bacteria
j because the instructions on the different disinfectants may recommend different dilutions/make solutions according to the recommended dilutions and repeat the experiment
k dip the control disk in sterile water and place on the agar
l only tests how effective the disinfectants are at killing one particular type of bacteria

8 **a** HIV = human immunodeficiency syndrome/Aids = acquired immune deficiency syndrome
b virus
c virus has been transferred from one species to another
d use of condoms/screening of blood/no sharing of needles by drug addicts
e they have HIV antibodies in their blood so they must have the HIV virus, though they may not have developed Aids at that point in time
f because the virus remains dormant for a long period of time (not known why)
g infections that occur because the immune system no longer functions properly
h because the virus mutates rapidly, making earlier vaccines ineffective

9 **a** milk and yoghurt (lactic acid) bacteria
b to sterilise the milk so that all other micro-organisms are killed
c yoghurt (lactic acid) bacteria
d to keep it warm so that bacteria multiply
e increases for first 40 minutes then fluctuates between 35°C and 38°C
f no, because the temperature of the culture was mostly above 35°C
g because this is the best temperature for bacterial growth
h water bath heating element turning on and off/heat produced by the action of the bacteria
i how acidic or alkaline a solution is
j temperature = 36°C/pH = 4.8
k steadily decreases then remains fairly constant after 120 minutes
l the acidity increases initially then levels off at around pH = 4.5
m the bacteria changing lactose sugar in the milk into lactic acid
n the mixture would have turned into semi-solid yoghurt

Unit 8: Transport In Plants

1 **a** Water passes into the roots hairs by osmosis. Osmosis is the passage of water *from a dilute solution* through a semi-permeable membrane *to a more concentrated solution*. The water in the soil has a weak solution of salts, which makes the dilute solution. The root hair cell wall is a semi-permeable membrane. It has small openings that allow small molecules such as water and salts to pass through. The cell sap in the root hair has a stronger solution making it a more concentrated solution.

b Water is pulled up the xylem in the stem from the roots. As water is lost from the leaves by transpiration, more is sucked up from the xylem vessels like water being sucked up a straw. There is a continuous flow of water from the roots to the leaves. This movement of water up the xylem is called the transpiration stream.

c The following factors cause an increased water loss from a leaf: windy conditions, low humidity, high temperatures and high light levels.

d Needle-like leaves have fewer stomata so water is not easily lost by transpiration.

e Phloem tubes are living and carry sugars to all parts of the plant. Xylem vessels are non-living and carry water upwards.

2 **a** light/sugar **b** pores/holes/openings
c day/day/night **d** starch
e xylem/sugar/water/upward **f** transpiration

3 **a** 220 g – 210 g = 10 g **b** 100 cm^3 – 88 cm^3 = 12 cm^3
c 1 cm^3 of water weighs 1 g

d The other 2 grams of water is used by the plant to keep its cells turgid and for other living processes inside the cells.

e The layer of oil prevents water evaporating into the air from the measuring cylinder.

f Transpiration would be different each day because of differing environmental conditions.

g If the plant loses more water than it uptakes, the cells will become flacid and the plant will wilt and droop.

4

Xylem	**Phloem**
Long tube-like cells	The cells of these vessels are alive
Sides of cell walls strengthened with lignin	Use energy provided by companion cells
These vessels are dead	Carry sugars away from leaves
Wood is mostly made from these cells	

Unit 9: History Of Planet Earth

1 **a** G **b** J **c** L **d** N
e A **f** I **g** B **h** M
i O **j** D **k** P **l** C
m R **n** F **o** H **p** K
q E **r** Q

2 **a** condensing is when a gas cools into a liquid/solidifying is when a liquid cools into a solid
b unicellular means made of only one cell/multicellular means made of many cells
c evolution involves the modification of an existing species or the formation of a new one/extinction occurs when all members of a species have died
d flora are plant species/fauna are animal species
e the ice cap is the ice-covering at the pole/a glacier is a river of ice coming from a mountainous area

3 **a** volcanic eruption and weathering
b mountain building and weathering
c earthquake

d erosion
e meteorite impact

4 **a** false – a very old planet
b true
c true
d true
e false – is continually changing
f true
g true
h false – are slowly rising
i true
j true
k true
l true

5 **a** break down into smaller atoms
b radioactivity
c the curve drops rapidly then levels off over time
d the number of parent atoms is halved
e increases rapidly at first then levels off over time
f young
g many more daughter atoms
h all become daughter atoms

6 **a** meteorite impacts
b because Earth's atmosphere causes many meteorites to burn up before hitting Earth
c as the moon has no atmosphere, there is no rain or wind to weather away craters
d from material originally formed at the birth of the solar system

7 **a** Carboniferous
b Cretaceous
c Cambrian
d Carboniferous
e Cambrian

8 Ice core studies show that when carbon dioxide levels go up global temperatures also rise; if global temperatures rise, then some of the ice in the polar ice caps and glaciers will melt causing the sea level to rise, which will flood low-lying islands

9 **a** Triassic
b end of the Cretaceous
c huge fires/fall in global temperature/loss of food resources
d huge craters/shock waves/vast fires/huge amounts of ash in the atmosphere/reduced sunlight reaching the surface
e global cooling would have occurred because of ash in the atmosphere preventing radiant energy reaching the surface
f because it would have taken some time for food reserves to disappear
g high levels of iridium atoms and heavy chromium atoms at the point in the rock strata where dinosaurs bones no longer appear/a fragment of the asteroid has been found

10 Type A Boundary
  a towards each other
  b in areas where mountain ranges and volcanoes occur
  c mountain building and volcanic activity
Type B Boundary
  a away from each other
  b along mid-ocean ridges/length of the Pacific Ocean
  c sea floor spreading/new crust formed/underwater volcanic activity
Type C Boundary
  a sideways past each other
  b along the Main Divide in the South Island of New Zealand
  c seismic activity/earthquakes and tsunami

11 a 15 layers **b** the bottom layer
c because the layers have been tipped till they are nearly vertical
d crumpling of layers when plates collide/mountain building
e by uplift when plates collide/uplift when mountain building occurs

12 a hotspot

b Savaiʻi because it is the island that is furthest away from the hotspot so it must have formed first.

c The plate on which the Sāmoan islands sit is moving from the east to the west.

d Wind and rain cause erosion (break down rock); plants and animals colonise the land and begin to change it; a coral reef grows around it; changing sea levels alter the coastline.

e Over millions of years erosion will wear down the hills and mountains and the islands will sink below the surface. The coral reef may be left behind to form a lagoon.

Unit 10: Fossil Fuels

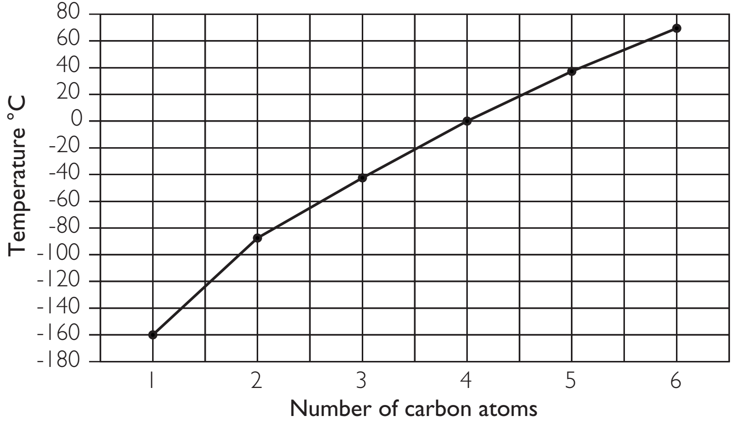
1 e, h, k, c, j, i, g, f, d, a, b

2 a hydrogen **b** mixture **c** refinery
d fractional distillation **e** column **f** boiling
g top **h** catalyst **i** shorter

3

Alkane	Formula
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}
Pentane	C_5H_{12}
hexane	C_6H_{14}
heptane	C_7H_{16}
Octane	C_8H_{18}

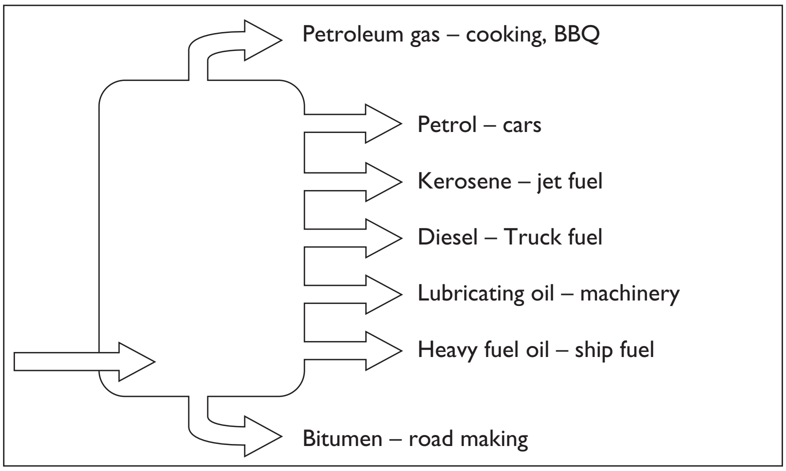
4 a



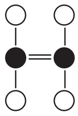
b As the number of carbon atoms increases, the boiling point increases.

c Pentane has a boiling point around 36°C.

5



6 **a**



b cracking

c butane and ethene

d heat and a catalyst

e $C_6H_{14} \rightarrow C_4H_{10} + C_2H_2$

Unit 11: Ecosystems

1 **a** food
b primary
c secondary
d waste
e decomposers
f chains
g webs
h biomass

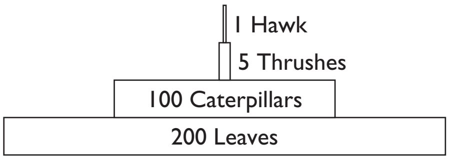
2 **a** Only green plants can capture energy from the sun. This is the way all energy enters an ecosystem.

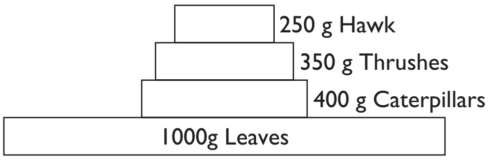
b **i** plants
ii aphid or moth larva or vole
iii ladybird or blue tit or spider or stoat

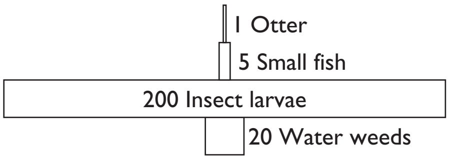
c Six – ladybird, blue tit, spider, owl, chiffchaff, stoat

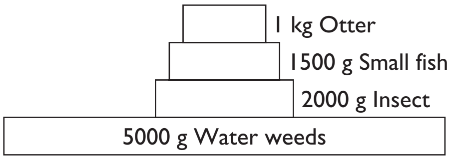
d plants → aphid → ladybird → blue tit → owl
plants → moth larva → spider → chiffchaff → owl

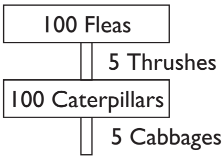
e **i** the number of plants would probably remain unchanged
ii the number of moth larva would increase because they are not being eaten by the spiders
iii the number of chiffchaffs would decrease because there are not enough spiders to sustain them.

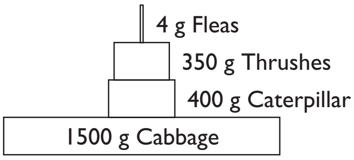












3 Pyramids of Numbers   Pyramids of Biomass

4 **a** $\frac{100 \text{ kJ}}{3000 \text{ kJ}} \times \frac{100}{1} = 33.33\%$ **b** $\frac{1900 \text{ kJ}}{3000 \text{ kJ}} \times \frac{100}{1} = 63.33\%$

c 100 g beef contains 1200 kJ of energy. Each square metre of grass gives 100 kJ that is used for growth. Therefore 12 square metres of grass are needed.

5 **a** fungi **b** waste **c** decomposers
d nutrients **e** increasing **f** fossil
g rainforest **h** greenhouse

6 **A** = Photosynthesis **B** = Respiration **C** = Decay by bacteria
D = Burning

7 **F** = Nitrogen compounds in animal waste
G = Nitrogen compounds in plants
H = Nitrogen compounds in the soil

8 **a** Reasons for large-scale deforestation include: to make grasslands for grazing animals; to build roads, mines and hydroelectricity dams; to harvest the timber; to make room for new cities.

b **i** Carbon dioxide levels are increasing.

ii Burning of forests to clear them increases carbon dioxide levels in the air.

iii Carbon dioxide is a greenhouse gas. It acts like a blanket around the earth and the atmosphere heats up. This causes more severe weather conditions and can lead to rising sea levels as the polar ice caps melt. The soil become less fertile. Because there are no trees, the top soil with all the nutrients is washed away.

c Agro-forestry; Setting up rainforest parks; Setting up nature reserves; Encouraging eco-tourism.

Unit 12: Exploring Space

1 **a** F **b** I **c** P **d** C
e A **f** J **g** M **h** D
i K **j** E **k** L **l** G
m O **n** B **o** R **p** N
q H **r** Q

2 **a** an observation involves passively watching and measuring a natural event/an experiment involves making a change and then observing the result

b a planet is a large heavenly body orbiting a star/a moon is a smaller heavenly body orbiting a planet

c a year is a period of time (365 days)/a light year is a huge astronomical distance (distance light travels in one year)

d a light telescope collects, focuses and magnifies light waves/a radio telescope collects and focuses radio waves

e a telescope collects, focuses and magnifies light/a spectrometer splits light up into a spectrum of colours for analysis

f a satellite is an object in orbit around a planet/a probe is a spacecraft sent to another planet, which may or may not end up orbiting

3 **a** 300 000 km/s
b the distance light travels in one year through space/9 500 000 000 000 km
c 4.4 years
d 4.4 x 9 500 000 000 000 km = 41 800 000 000 000 km
e 8.6 x 9 500 000 000 000 km = 81 700 000 000 000 km

4 **a** false – an observational science
b true **c** true **d** true
e false – all electromagnetic waves travel at the speed of light through space
f true **g** true **h** true
i true **j** true

5 **a** the orbit periods get longer
b the further away a planet is from the Sun, the lower its mean surface temperature
c because the more distant a planet is the less solar radiation it will receive
d larger planets have more moons than smaller ones

6 **a** the air is clearer due to less pollutants and water vapour in the atmosphere/less light pollution away from cities/the atmosphere is less turbulent/the atmosphere is less absorptive
b the telescope is rotated on its base to face the star, then elevated until its axis lines up with the star
c during the daytime, as the Sun's light obscures the stars
d they could see both southern and northern hemisphere stars
e there is no atmosphere to distort the light from distant stars/there are no cloudy nights/all wavelengths can be observed all of the time
f building and launching the space telescope is an extremely expensive exercise
g it was transported into orbit aboard the space shuttle
h they are solar panels that generate electricity to power the telescope
i by rotating the telescope until its axis points at the star's co-ordinates in space (reaction wheels are turned in one direction, which cause the telescope to rotate in the opposite direction)
j the space telescope is orbiting in an endless curve matching the curve of Earth's surface
k yes, because above the atmosphere the sky is black not blue, and the stars can be seen even when the telescope is exposed to the Sun's light

7 **a** Southern Africa Large Telescope
b light waves, infra-red waves, ultra-violet waves
c because there is no atmosphere on the Moon and therefore a candle could not burn
d because they are much cheaper to manufacture/they can be interchanged
e they will wait until the time of night when the elevation of the star is 37° and then rotate the telescope to point at it
f because the location of the image formed by the primary mirror will shift as the Earth rotates and the imaging mirrors need to move to keep track of it
g conventional telescopes are usually fully steerable and can be elevated up and down as well as rotated around horizontally
h to avoid light pollution and to be at a high enough altitude to escape water vapour in the atmosphere

8 **a** they are transported into orbit aboard spacecraft such as the space shuttle

b by the large solar panels that intercept light energy from the Sun and convert it into electrical energy, which is then stored in batteries as chemical energy

c oxygen must be transported up to the space station and stored on board till required

d as it orbits Earth it moves in and out of radiation coming from the Sun, so it experiences temperature extremes

e special materials insulate the interior of the station from excessive heat loss or gain, electrical energy is also used to heat or cool the interior

f waste water is purified on board and recycled

g it may become possible to grow some crops hydroponically on board under artificial light

h because they are in free-fall as the space station falls in an endless curve around Earth

i muscle strength would deteriorate unless suitable exercises are done to maintain muscle tone, especially in the legs

j the space station is brighter than the brightest star and it travels rapidly across the night sky in only a few minutes

k a shooting star only travels a short distance across the night sky before it burns up in the atmosphere

Unit 13: Inside Atoms

1 **a** H **b** O **c** E **d** K
e D **f** M **g** B **h** P
i G **j** Q **k** A **l** N
m F **n** C **o** J **p** R
q I **r** L

2 **a** the nucleus is the dense central area of an atom containing protons and neutrons/an electron cloud is the space around the nucleus occupied by the electrons

b protons are positively charged particles found in the nucleus/electrons are negatively charged particles that fly around the nucleus

c mass number is the number of protons and neutrons in the nucleus/atomic number is the number of protons in the nucleus

d atoms are the building blocks of matter/elements are substances that contain identical atoms

e periods are rows on the Table/groups are columns

3

Particle	Mass	Charge	Location
proton	heavy	positive	nucleus
neutron	heavy	neutral	nucleus
electron	light	negative	electron cloud

4 **a** 5 protons **b** 6 neutrons
c 5 electrons **d** mass number = 5 + 6 =11
e atomic number = 5
f yes, equal numbers of protons and electrons

5 **a** true **b** true
c false – protons are positively charged, electrons are negative and neutrons are neutral
d true
e false – like charges repel and unlike charges attract
f false – equal numbers of protons and electrons
g false – the further it will be from the nucleus
h true **i** true
j false – in the outermost shell
k true **l** true

6 **a** F **b** Ca **c** I **d** Cl
e C **f** He **g** Si **h** Na
i Pb **j** Zn **k** K **l** N
m Mg **n** P **o** Fe **p** Hg
q Cu **r** Ar **s** Ne **t** Al
u Mn **v** Br **w** Ag **x** Ni
y B **z** Li

7 **a** iron **b** zinc **c** silver
d sulfur **e** carbon **f** lithium
g sodium **h** calcium **i** hydrogen
j mercury **k** nitrogen **l** iodine
m oxygen **n** magnesium **o** potassium
p beryllium **q** silicon **r** neon
s bromine **t** fluorine **u** aluminium
v lead **w** boron **x** phosphorus
y helium **z** manganese

8 no partially filled shells – He/Ne/Ar/Kr/Xe/Rn in group 18, they do not react with other atoms

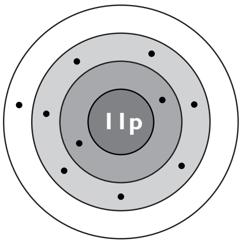
9 **a** hydrogen **b** helium **c** carbon
d nitrogen **e** neon **f** sodium
g magnesium **h** aluminium **i** sulfur
j chlorine **k** calcium **l** iron
m copper **n** zinc **o** lead

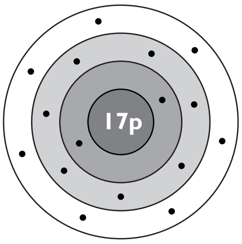
10 **a** 1 **b** 13 **c** 3 **d** 6
e 20 **f** 11 **g** 12 **h** 16
i 17 **j** 7 **k** 9 **l** 30

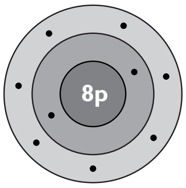
11 **a** 26 **b** 1 **c** 80 **d** 82
e 12 **f** 2 **g** 16 **h** 6
i 35 **j** 8 **k** 10 **l** 7

12 **a** because the elements are arranged in periods
b 75 elements
c in order of their atomic numbers
d a row of elements
e Period 2 – Li/Be/B/C/N/O/F/Ne
f a column of elements
g Group 2 – Be/Mg/Ca/Sr/Ba/Ra
h Group 18 – He/Ne/Ar/Kr/Xe/Rn
i metals on the left and in the middle
j non-metals on the right
k Group 18
l Group 1
m Group 17

13







a 1 valence electron
b 7 valence electrons
c 6 valence electrons

14

Element	Protons	Neutrons	Mass Number
lithium	3	4	7
carbon	6	6	12
fluorine	9	10	19
aluminium	13	14	27
chlorine	17	18	35

15 **a** 9 electrons
b 9 protons
c atomic number = 9
d fluorine
e mass number = 19
f 7 valence electrons
g non-metal

Unit 14: Atom Arrangements

1 **a** E
b G
c B
d D
e I
f C
g A
h M
i P
j F
k O
l J
m Q
n N
o L
p H
q R
r K

2 **a** a molecule is a group of atoms involved in sharing electrons/a lattice is a regular array of billions of atoms
b an element is a substance made of identical atoms/a compound is a substance made of non-identical atoms that are bonded
c a molecular compound is a group of non-identical atoms sharing electrons/an ionic compound is a substance in which atoms are held together by ionic bonds
d a covalent bond occurs when atoms are sharing electrons/an ionic bond occurs after electrons have been transferred from one atom to another
e a simple ion is just a single charged atom/a complex ion is usually a charged group of atoms

3 **a** nitrogen N_2
b oxygen O_2
c fluorine F_2
d chlorine Cl_2
e water H_2O
f carbon dioxide CO_2
g carbon monoxide CO
h nitrogen dioxide NO_2
i ammonia NH_3
j sulfur trioxide SO_3
k hydrogen H_2
l sulfur dioxide SO_2
m group of atoms involved in sharing electrons
n N_2 O_2 F_2 Cl_2 H_2
o H_2O CO_2 CO NO_2 NH_3 SO_3 SO_2

4 **a** true
b true
c false – billions of atoms
d true
e true
f true
g true
h false – non-identical atoms bonded together
i false – cannot form molecules/can form ions only

j true **k** true
l false – opposite charge ions **m** true

5 **a** CO_2 has 1 carbon atom and 2 oxygens
b H_2O has 2 hydrogen atoms and 1 oxygen
c O_2 has 2 oxygen atoms
d CO has 1 carbon atom and 1 oxygen
e O_3 has 3 oxygen atoms
f Cl_2 has 2 chlorine atoms
g NO_2 has 1 nitrogen atom and 2 oxygens
h N_2O_5 has two nitrogen atoms and 5 oxygens
i HCl has 1 hydrogen atom and 1 chlorine
j NO has 1 nitrogen atom and 1 oxygen
k NH_3 has 1 nitrogen atom and 3 hydrogens
l CH_4 has 1 carbon atom and 4 hydrogens
m SO_2 has 1 sulfur atom and 2 oxygens
n SO_3 has 1 sulfur atom and 3 oxygens
o S_8 has 8 sulfur atoms

6 **a** F^- **b** O^{2-} **c** Ca^{2+} **d** Al^{3+}

7 **a** He, Ne and Ar **b** keep their electrons **c** tend to lose electrons
d lose two electrons **e** share electrons **f** gain two electrons
g can do both
h non-metal atoms will either share, take or keep their electrons depending on how full their shells are
i O F S Cl

8 **a** H^+ **b** Li^+ **c** Be^{2+}
d O^{2-} **e** F^- **f** Na^+
g Mg^{2+} **h** Al^{3+} **i** S^{2-}
j Cl^- **k** K^+ **l** Ca^{2+}

9 **a** hydroxide **b** nitrate **c** carbonate
d bicarbonate **e** sulfate **f** ammonium

10 **a** lose **b** positive **c** molecules
d share/gain **e** metal **f** molecules
g negative **h** positive/losing/negative/gaining

11 **a** diamond is a very hard, transparent crystal/graphite is a soft, black substance
b yes
c alternative forms of an element
d not strong enough to take electrons from other atoms or weak enough to lose them
e share electrons with other atoms
f covalent/strong
g yes, as their atoms are covalently bonded/do form lattices
h the lattice of atoms in diamond is three-dimensional giving a rigid structure/the lattice of atoms in graphite is constructed of two-dimensional sheets which slide over each other

12 **a** 1 Na^+ : 1 Cl^- **b** 2 Na^+ : 1 O^{2-} **c** 1 Mg^{2+} : 1 O^{2-}
d 1 Mg^{2+} : 2 Cl^- **e** 2 Al^{3+} : 3 O^{2-}
f $CaCl_2$ has 1 calcium ion to every 2 chloride ions
g K_2O has 2 potassium ions to every oxide ion
h KCl has 1 potassium ion to every chlorine ion
i $Mg(OH)_2$ has 1 magnesium ion to every 2 hydroxide ions
j $CaCO_3$ has 1 calcium ion to every carbonate ion

k Na_2SO_4 has 2 sodium ions to every sulfate ion
l $Mg(NO_3)_2$ has 1 magnesium ion to every 2 nitrate ions
m NH_4OH has 1 ammonium ion to every hydroxide ion
n $Al(OH)_3$ has 1 aluminium ion to every 3 hydroxide ions

Unit 15: Metals

1 **a** G
b J
c C
d I
e A
f L
g F
h N
i D
j R
k E
l M
m K
n P
o H
p Q
q O
r B

2 **a** metals are strong, shiny, silvery solids that are good conductors and can be readily worked into new shapes/non-metals do not have these properties
b physical properties are features that do not involve chemical reactions/chemical properties relate to chemical reactions that the substance undergoes
c ductility means able to be stretched into a wire/malleability means able to be hammered or squashed into a new shape
d pure metals are made of one type of element only/alloys consist of a mixture of different elements
e combustion is the rapid oxidation of a substance through burning/tarnishing is the slow oxidation of a metal in air over time

3 **a** copper and gold
b solid/exception is mercury
c –39°C
d lead, mercury, silver and gold
e silver/copper is the best cheap conductor
f copper is best/mercury is the poorest
g copper and iron are the strongest/lead is the weakest
h aluminium, silver and gold

4 **a** true
b false – most metals
c false – do not include the reactivity of the metal
d true
e true
f true
g false – an alloy is usually a mixture of metals
h false – become positive ions
i true
j false – some metals
k true
l false – an unreactive metal holds tightly to its free electrons

5 **a** jewellery – silver and gold because they are resistant to corrosion and are expensive
b bridges – iron (steel) for strength and cheapness
c aircraft wings – aluminium for lightness (magnesium is too reactive)
d electrical wires – either copper or aluminium (gold and silver are too expensive)
e thermometers – mercury as it is the only liquid metal at room temperature
f fishing sinkers – lead as it is heavy and cheap
g ladders – aluminium as it is light and strong
h car bodies – iron (steel) for strength
i cooking pots – copper as it is a very good heat conductor
j scissors – iron (steel) for strength

6 **a** most metals are dense because the atoms are tightly packed
b the free electrons allow metals to conduct electricity
c the free electrons in metals transfer heat energy rapidly from atom to atom
d the strength of metallic bonding makes most metals solid at room temperature
e metals mostly have high MPs because lots of heat energy is required to free up atoms from the metallic bonding
f metals are ductile because metallic bonding holds the metal atoms together as it is stretched
g metals are malleable because the layers slide over each other

7 **a** metals lose their free electrons in reactions
b positive ions
c a metal oxide
d Metal + oxygen ➔ metal oxide
e hydrogen gas and a metal hydroxide
f Metal + water ➔ metal hydroxide + hydrogen gas
g hydrogen gas and a salt
h Metal + acid ➔ salt + hydrogen gas

8 **a** Ca > Mg > Al > Zn > Fe > Pb > Cu
b unreactive

9 **a** alloys
b mixture of several elements where the major element is a metal
c by mixing in other elements when the metal is in a molten state during smelting
d hardness/strength/corrosion resistance/melting point
e bronze is an alloy of copper and tin, which gave humans a reasonably strong metal for weapons and tools
f brass is an alloy made from copper and zinc; it was used to make important machine parts on steam engines during the Industrial Revolution
g steel is much stronger and is more resistant to rusting and corrosion
h 'silver' coins are made of a copper-nickel alloy/'gold' coins are made of an aluminium-copper alloy
i 'designer alloys' are special alloys developed for very specific purposes

10 **a** aluminium, copper and lead
b Ca > Mg > Zn >Fe > Al/Cu/Pb
c aluminium/because it has a thin, resistant oxide coating that prevents other reactions
d hydrogen gas – insert a flame and the gas pops
e calcium chloride
f iron chloride
g magnesium chloride
h zinc chloride
i Calcium + hydrochloric acid ➔ hydrogen gas + calcium chloride
j Iron + hydrochloric acid ➔ hydrogen gas + iron chloride
k Magnesium + hydrochloric acid ➔ hydrogen gas + magnesium chloride
l Zinc + hydrochloric acid ➔ hydrogen gas + zinc chloride

11 **a** $ZnCl_2$ **b** MgO **c** $CaCl_2$
d Al_2O_3 **e** $CuCl_2$ **f** $NaCl$

Unit 16: Carbon Compound Families

1 **a** F
b K
c M
d Q
e A
f N
g G
h H
i C
j J
k P
l D
m R
n E
o O
p L
q I
r B

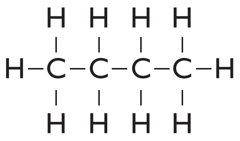
2 **a** a substance that is burnt to release heat energy
b a fuel, oxygen gas and a flame to ignite the gas
c water vapour, carbon dioxide, carbon monoxide, carbon (soot) and unburnt alkanes
d petrol and diesel
e CNG and LPG
f CNG as a gas/LPG, meths, petrol, diesel as liquids/paraffin as a solid
g CNG, LPG, meths (possibly), petrol and diesel

3 because carbon atoms can bond with up to four other atoms, a huge number of molecules can exist based on long chains of carbon atoms

4 **a** false – fuels release energy when burnt
b false – fuels can be solids, liquids or gases
c true
d true
e true
f true
g true
h false – boiling points rise
i true
j true
k false – are not hydrocarbons
l true

5 **a** yes
b four
c C_4H_{10}
d alkane
e butane
f (see below)
g yes
h C_8H_{18}
i alkane
j see below
k yes
l C_3H_6
m alkene
n propene
o (see below)
p because it has an oxygen atom
q C_2H_5OH
r ethanol

f



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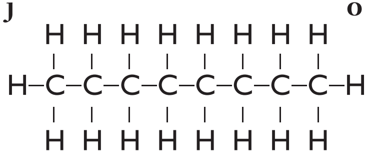

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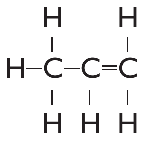

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6 **a** about 40°C
b the fourth one, butane
c rises rapidly at first, then continues rising evenly
d as the number of carbon atoms in the alkane molecules increases, the boiling point rises as well
e room temperature
f methane, ethane, propane, butane
g pentane, hexane, heptane, octane, nonane, decane
h no, you need to have the melting point data

7 **a** propane
b decane
c the curve is level to start with then falls a bit before increasing
d for alkane molecules with more than three carbons the melting point increases as the number of carbon atoms in the molecule increases

e none will be solids as all have melting points below room temperature
f need their boiling points as well

8 **a** land that is submerged under still water
b grazing animals and termites
c dead material to feed on and the absence of oxygen gas
d bacteria and fungi that cause the breakdown of dead organisms and wastes
e methane and carbon dioxide gases
f in tanks where bacteria attack the sewage sludge in the absence of oxygen
g burnt to generate electricity and used as a fuel in cars
h carbon dioxide gas and water vapour

9 **a** methane **b** oxygen
c complete combustion **d** water vapour and carbon dioxide gas
e methane + oxygen ➔ water + carbon dioxide
f $CH_4 + 2O_2 \rightarrow 2H_2O + CO2$ **g** yellow flame
h methane + oxygen ➔ carbon monoxide + carbon dioxide + carbon + water
i carbon monoxide **j** because of the soot
k more heat is released/less pollution/equipment does not turn black

10 **a** sugars
b ethanol and carbon dioxide
c makes it rise because of the carbon dioxide gas produced
d evaporates during cooking
e provides the froth when the can or bottle is opened
f ethanol

Unit 17: Energy And Change

1 **a** E **b** J **c** M **d** B
e O **f** A **g** G **h** P
i D **j** R **k** L **l** C
m I **n** F **o** Q **p** H
q K **r** N

2 **a** active energy is where energy is involved in doing something/potential energy is where energy is stored is some way
b an energy transfer occurs when the type of energy passed on remains the same/an energy transformation occurs when the type of energy passed on is changed
c energy input is the energy supplied in an energy transformation/energy output is the energy produced in a transformation
d useful energy is energy that is able to be utilised for the purposes of the object/waste energy is energy that is not able to be utilised

3 **Active energy** – kinetic, heat, electrical, sound, light
Potential energy – elastic, chemical, gravitational

4 **a** chemical energy into heat and light
b kinetic energy into electricity
c gravitational energy into kinetic

5 **a** false – energy is not a substance **b** true
c true **d** true **e** true
f false – heat energy depends on the temperature and mass of the object
g true **h** true **i** true

j false – in many energy transformations some of the useful energy is lost
k true

6

Situation	Energy Type	Factors Affecting Energy
can of petrol	chemical	energy in bonds
diver on platform	gravitational	height and mass
red-hot horseshoe	heat	temperature and mass
stretched catapult	elastic	stretch and rubber thickness
speeding skater	kinetic	speed and mass
shock from mains	electrical	current and voltage

7 **a** solar panel in sunlight
b bungee jumper slowing
c sky rocket taking off
d firing an arrow
e bungee jumper leaping
f steam engine in action
g going up in a lift
h glowing stove element
i a battery charging

8

Appliance	Input	Useful	Waste	Output
toaster	1500	300	1200	1500
heater	2400	2200	200	2400
radio	60	45	15	60
jug	2000	1400	600	2000
lamp	100	10	90	100
shaver	200	130	70	200

9

Appliance	Useful	Input	Efficiency
toaster	300	1500	20%
heater	2200	2400	92%
radio	45	60	75%
jug	1400	2000	70%
lamp	10	100	10%
shaver	130	200	65%

a heater, radio, jug, shaver, toaster, lamp

b heat

c so that the two amounts can be fairly compared

10 **a** electrical energy into kinetic energy
b sound and heat
c input energy is electrical energy/output energy includes kinetic, heat and sound energy
d because it cannot be utilised by the drill
e friction between moving parts converts kinetic into heat energy
f smooth surfaces/use of lubricants/use of ball-bearings
g because there will always be some friction between moving parts which will convert kinetic energy into heat
h because the heat produced by the motor can also be used to help dry

11 a by 10 kg each time
b kinetic energy of 50 kg trolley is about 625 J, kinetic energy of 100 kg trolley is about 1250 J
c kinetic energy doubles when mass doubles
d kinetic energy is directly proportional to the mass of the object

12 a speed increases regularly (by 1 m s^{-1} each time)
b kinetic energy increases by larger amounts each time
c kinetic energy at 4 m s^{-1} is about 650 J, kinetic energy at 8 m s^{-1} is about 2600 J
d kinetic energy quadruples as speed doubles
e kinetic energy is proportional to the square of the speed

Unit 18: Current, Circuits And Components

1 a I **b** M **c** G **d** P
e C **f** R **g** K **h** A
i E **j** Q **k** B **l** O
m F **n** J **o** H **p** D
q L **r** N

2 a a conductor allows a current to pass through it/an insulator does not allow a current to pass through it
b a solar cell converts light energy into electrical energy/a chemical cell converts chemical energy into electrical energy
c a series circuit has all components in a single loop/a parallel circuit has components on different branches
d an ammeter measures the size of the current flowing/a voltmeter measures the amount of electrical energy gained or lost by the current

3 a three metal prongs are conductors/plastic body of plug acts as an insulator
b two metal prongs are conductors/plastic body of plug and plastic coating on wires act as insulators
c copper wires are conductors/plastic coating on wires acts as an insulator
d silvery metal dimples on base of the light bulb are conductors/glass bulb acts as an insulator
e terminals act as conductors/plastic coating of the battery acts as an insulator

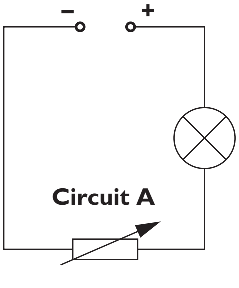
4 a true **b** true
c false – electrons are the particles
d false – an electrical conductor will have many free electrons
e true **f** true
g true
h false – from the negative terminal of a battery around to the positive
i true **j** false – said to be in parallel
k true

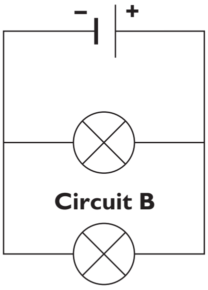
5 a cell, lamp, wire, switch **b** cell
c wire **d** lamp
e yes – because the lamps are glowing

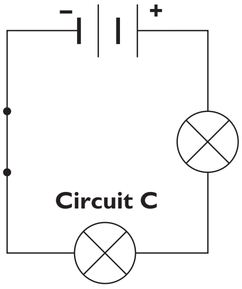
6 a power pack **b** ammeter **c** switch and lamp
d rheostat **e** cell **f** voltmeter

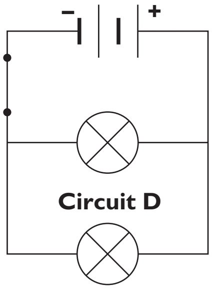
7 a to vary the resistance in the circuit/to vary the current in the circuit/to dim the lamp

b series
c because the lamp is glowing
d see Circuit A below
e to provide electrical energy/produce electricity
f no
g same current in each
h see Circuit B below
i turn current on or off
j cells in series/bulbs in series too
k other bulb goes out/circuit broken/no current anywhere
l see Circuit C below
m in parallel
n in series
o other bulb would still glow
p see Circuit D below









8 **a** because it is a high energy electrical current
b no free electrons
c tops of clouds are positive/bottoms are negative
d convection currents in clouds
e because the bottoms of clouds are negatively charged and the ground is positively charged
f turns air molecules into ions
g the supply of free electrons when the air is ionised
h because leaders from the ground usually leap up from tall objects
i rod on highest part of a building attracts lightning strikes coming towards the building and passes electricity through a conductor into the ground

9 **a** series
b to limit the current flowing in the circuit
c go out
d three
e in series
f in parallel
g both go out
h top lamp glows and bottom one goes out
i power pack
j series
k current decreases
l gets brighter
m in series
n in parallel
o positive terminal

Unit 19: Current And Voltage

1 **a** D
b H
c K
d M
e B
f R
g A
h P
i C
j O
k F
l J
m Q
n L
o E
p I
q G
r N

2 **a** charge is a property that is either positive or negative/current is the flow of charge
b an analogue meter has a scale to read off/a digital meter provides the reading in digits
c current is a flow of electrons/voltage is the energy gained or lost by electrons in the current

d voltage supply is the energy gained by electrons as they pass through the power supply/voltage loss in the energy lost by electrons as they pass through a component
e a component is any part of an electrical circuit/a terminal is a connection point on a component

3 a charge/electrons/conductors/**I**/ampere/amp/ammeter/force field/power
b potential/electrons/current/power/loss/gain/**V**/volt/voltmeter

4 a ammeter **b** analogue
c amperes or amps **d** because it has two different ranges

5 a true **b** true
c false – a digital meter, an analogue meter has a scale to read off
d true **e** true
f false – smallest share of the current
g false – positive terminal of the power supply
h true **i** true
j true

6 a ammeter/in amperes or amps
b 0–5 amps **c** interval is equal to 0.1 amp
d to the nearest 0.1 amp
e meter A = 0.3 A/meter B = 4.7 A/meter C = 1.1 A

7 a in series next to component **b** in parallel around component
c to the positive terminal of the power supply

8 a in series **b** positive/red terminal
c needle has moved forward on the scale
d about 0.5 A **e** in parallel
f positive/red terminal **g** about 5.5 V
h 6 V
i less than/meter or voltage dial inaccurate or voltage lost elsewhere in circuit

9 a a device that transforms another type of energy into electrical energy
b a chemical cell transforms chemical energy into electrical/a solar cell converts light energy into electrical
c 6 J
d because other power sources would become exhausted after a time
e last a long time/free energy source
f can't work in the dark/large surface area needed for a reasonable current
g substance that conducts electrons, but not as well as metals
h when light waves are absorbed, the two layers develop different charges
i a current is produced and the electrons gain potential energy

10 a in series **b** two amps in both meters
c in parallel **d** six amps
e the current in a series circuit is the same at all points/the current in a parallel circuit is shared between the branches

11 a both lamps and cells in series
b 1.5 V + 1.5 V = 3 V **c** 1.5 V
d lamps in parallel/cells in series
e 3 V, as voltage drop across parallel components is identical to the voltage gain

Unit 20: Resistance, Power And Energy

1 **a** L **b** D **c** N **d** R
e I **f** B **g** K **h** A
i Q **j** G **k** O **l** F
m C **n** P **o** J **p** H
q E **r** M

2 **a** a conductor allows electrons to travel through it freely/a resistor opposes the flow of electrons
b a fixed resistor has a set resistance/the resistance of a rheostat can be varied
c resistance is a component's opposition to the current/power is the rate at which a component transforms energy
d total energy is the energy used by a component over a period of time/power is the amount of energy used per second by a component

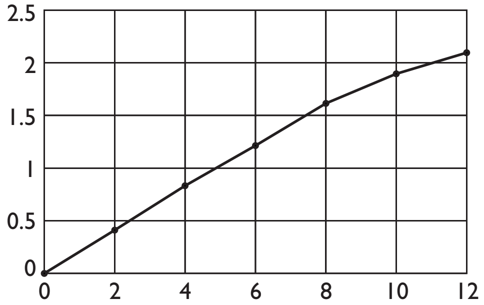
3

Quantity	Symbol	Unit	Unit Symbol
Current	**I**	ampere	A
Voltage	**V**	volt	V
Resistance	**R**	ohm	**Ω**
Power	**P**	watt	W

4 **a** **R = V ÷ I** **b** **P = V x I** **c** **I = V ÷ R** **d** **V = P ÷ I**

5 **a** true **b** false – less current will flow
c true **d** true **e** true
f true **g** true **h** true
i false – proportional to current and voltage
j true

6 **a** current increases **b** yes **c** see opposite
d a straight sloping line initially, but then it curves
e because the resistance in the circuit is increasing
f as the bulb heats up, its resistance increases



7 **a** **R = V ÷ I** **b** **R** = 10.2 ÷ 2.5 = 4.08 = 4.1 Ω
c **P = V x I** **d** **P** = 10.2 x 2.5 = 25.5 W
e **E = P x t** **f** **E** = 25.5 x 90 = 2295.0 J
g 10% of 2295 J = 0.1 x 2295 = 229.5 J
h 90% of 2295 J = 0.9 x 2295 = 2065.5 J

8 toaster 960 W/television 48 W/shaver 3 W/radio 1.5 W/fan 480 W/lamp 72 W

9 **a** electricity that comes out of a three-pin power point
b kilowatt-hour **c** 3 600 000 J **d** 20 kilowatt-hours
e 20 x 3 600 000 = 72 000 000 J **f** 20 x 12‘ō = $2.40
g advantage – save on power bill/disadvantage – hot water cannot be reheated in daytime

10 toaster 60 **Ω**/television 1200 **Ω**/shaver 12 **Ω**/radio 6 **Ω**/fan 120 **Ω**/lamp 800 **Ω**

11 **a** 1.5 V **b** **R = V ÷ I** = 1.5 ÷ 0.5 = 3 Ω
c total resistance = 3 Ω + 3 Ω = 6 Ω
d **I = V ÷ R** = 3 ÷ 3 = 1 A
e total current = 1 A + 1 A = 2 A

Unit 21: Speed And Acceleration

1

a	E	**b**	H	**c**	L	**d**	O
e	B	**f**	R	**g**	A	**h**	J
i	C	**j**	I	**k**	F	**l**	D
m	Q	**n**	P	**o**	G	**p**	N
q	K	**r**	M				

2 **a** a speedometer measures the instantaneous speed of an object/ an accelerometer measures the instantaneous acceleration of an object

b acceleration occurs when an object's speed is increasing/deceleration occurs when an object's speed is decreasing

c the instantaneous speed of an object is its speed at one point in time/ average speed is the mean speed of an object over a journey

d negative acceleration is when an object is slowing down/positive acceleration is when an object is speeding up

3

distance	d	metres	m
time	t	seconds	s
speed	v	metres per second	m s^{-1}
acceleration	a	metres per second squared	m s^{-2}

4 10 km hr^{-1} = 2.8 m s^{-1} 50 km hr^{-1} = 14.0 m s^{-1}

80 km hr^{-1} = 22.4 m s^{-1} 100 km hr^{-1} = 28.0 m s^{-1}

3.6 km hr^{-1} = 1 m s^{-1} 18.0 km hr^{-1} = 5 m s^{-1}

36.0 km hr^{-1} = 10 m s^{-1}

5 **a** true **b** true **c** true

d false – means it is slowing down **e** true

f false – measures instantaneous speed **g** true

h true **i** true

j false – gives its acceleration **k** true

6

Event	Distance	Fastest Time	Speed (m s^{-1})
swimming	4000 m	2610 s	1.5
cycling	120 km	9605 s	12.5
running	32 km	9913 s	3.2

a so that the speeds can be compared

b km hr^{-1}

c cycling – running – swimming

d swimming is so slow because water is a dense medium to move through/ running and cycling are faster as air is a less dense medium to pass through/cycling is fastest because the gearing multiplies the distance travelled

7 **a** distance-time graph **b** constant speed

c sprinter is accelerating

d $\mathbf{\Delta d}$ = 88 m and $\mathbf{\Delta t}$ = 8 s, so slope = $\mathbf{\Delta d} \div \mathbf{\Delta t}$ = 88 m ÷ 8 s = 11 m s^{-1}

e $v_{av} = d \div t$ = 88 m ÷ 8 s = 11 m s^{-1}

f $v_{av} = d \div t$ = 100 m ÷ 10 s = 10 m s^{-1}

g because the average speed for the whole journey includes the first two seconds in which the athlete is accelerating to top speed, whilst during the last 8 seconds he is running at top speed all the time

8 **b** car A accelerates at a faster rate than car B/both cars accelerate at constant rates

c for car A: $\mathbf{\Delta v}$ = 185 km hr^{-1} = 51.8 m s^{-1} and $\mathbf{\Delta t}$ = 10 s, so slope = $\mathbf{\Delta v} \div \mathbf{\Delta t}$ = 51.8 m s^{-1}÷ 10 s = 5.2 m s^{-2} ; for car B: $\mathbf{\Delta v}$ = 135 km hr^{-1} = 37.8 m s^{-1} and $\mathbf{\Delta t}$ = 10 s, so slope = $\mathbf{\Delta v} \div \mathbf{\Delta t}$ = 37.8 m s^{-1}÷ 10 s = 3.8 m s^{-2}

d the acceleration of car A is 5.2 m s^{-2} whilst the acceleration of car B is 3.8 m s^{-2}

9 a fastest average speed v_{av} = 100 m ÷ 9.79 s = 10.21 m s^{-1}

b because there is a period at the start of the race when the athlete's speed is less than maximum speed so average speed must be less than maximum speed

c about 40 m

d thrust (or the reaction to thrust)

e the athlete's body compressing air in front which pushes back against the athlete

f it increases

g remains constant

10 a speed-time graph

b acceleration

c acceleration in first five seconds, constant speed for two seconds, then deceleration for last three seconds

d acceleration = $\mathbf{\Delta v} \div \mathbf{\Delta t}$ = (7.5 m s^{-1} – 0 m s^{-1}) ÷ 5 s = 7.5 m s^{-1} ÷ 5 s = 1.5 m s^{-2}

e zero

f acceleration = $\mathbf{\Delta v} \div \mathbf{\Delta t}$ = (0 m s^{-1} – 7.5 m s^{-1}) ÷ 3 s = –7.5 m s^{-1} ÷ 3 s = –2.5 m s^{-2}

11 a **Task**: find average speed in m s^{-1} to 1 dp **Quantities**: t = 12 min and d = 3250 m **Formula**: v_{av} = d ÷ t **Modify units**: t = 12 x 60 s = 720 s **Substitute**: v_{av} = 3250 m ÷ 720 s **Calculate**: 3250 ÷ 720 = 4.5138888
Round off: 4.5138888 becomes 4.5 **Answer**: 4.5 m s^{-1}

b **Task**: find acceleration in m s^{-2} to 2 dp **Quantities**: t = 11 s, initial speed = 62 m s^{-1}, final speed = 140 m s^{-1} **Formula**: a = $\mathbf{\Delta v} \div \mathbf{\Delta t}$ **Modify units**: OK **Substitute**: a = (140 m s^{-1} – 62 m s^{-1}) ÷ 11 s **Calculate**: (140 – 62) ÷ 11 = 7.090909 **Round off**: 7.090909 becomes 7.09 **Answer**: 7.09 m s^{-2}

c **Task**: find acceleration in m s^{-2} to 2 dp **Quantities**: t = 25 s, initial speed = 100 km hr^{-1}, final speed = 0 km hr^{-1} **Formula**: a = $\mathbf{\Delta v} \div \mathbf{\Delta t}$ **Modify units:** 100 km hr^{-1} = 28 ms^{-1} and 0 km hr^{-1} = 0 ms^{-1} **Substitute**: a = (0 m s^{-1} – 28 m s^{-1}) ÷ 25 s **Calculate**: –28 ÷ 25 = –1.12 **Round off**: –1.12 stays as –1.12 **Answer**: –1.12 m s^{-2}

Unit 22: Force, Mass And Momentum

1 a C **b** G **c** J **d** M
e A **f** N **g** P **h** B
i I **j** Q **k** E **l** R
m D **n** K **o** L **p** O
q H **r** F

2 a with a contact force, the object causing the force must touch another object to make it move/with a non-contact force, the object causing the force does not need to touch another object to make it move

b the magnitude of a force is the size or strength of the force/the direction of a force is the direction in which it will move an object

c mass is the amount of matter in an object/weight is the force of gravity acting on an object
d balanced forces do not produce any change in the motion of an object/unbalanced forces will cause a free object to accelerate, decelerate or change direction

3 **a** If the net force on an object increases, then its acceleration will increase.
b If the total mass of an object increases, then its acceleration will decrease.
c If the speed of an object increases, then its momentum will increase.
d If the mass of an object increases, its momentum will increase provided its speed does not fall.

4 **a** net force = 5 N downward **b** net force = 21 N upward
c net force = 2 N to left **d** net force = 28 N to left

5 **a** true **b** true
c false – is sometimes required to keep an object in motion
d true
e false – transfer kinetic energy to objects
f false – example of a non-contact force
g true **h** true
i false – can cause a free object to accelerate, decelerate or change its direction
j true **k** false – in newtons
l true **m** true

6 **a** thrust is F_1 **b** weight is F_2 **c** friction is F_3
d support is F_4
e friction occurs between the object and the surface beneath
f net force in the vertical plane is zero
g none
h net force in the horizontal plane is 7 N toward the right
i object will accelerate toward the right
j balanced in the vertical plane and unbalanced in the horizontal plane
k balanced forces cause no change in an object's motion
l unbalanced forces will cause a free object to accelerate, decelerate or change direction

7 **a** momentum = mass x speed
b momentum = 0.20 kg x 20 m s^{-1} = 4.0 kg m s^{-1}
c momentum = 0.20 kg x 10 m s^{-1} = 2.0 kg m s^{-1}
d momentum = 0.18 kg x 20 m s^{-1} = 3.6 kg m s^{-1}

8 **a** slope is a straight line
b as the net force increases, the acceleration of the trolley increases
c acceleration doubles too
d acceleration is directly proportional to net force
e curve slopes downwards rapidly then levels off
f about 0.8 m s^{-2}
g as the mass of the trolley is increased, the acceleration of the trolley decreases
h acceleration decreases from 5 m s^{-2} to 2.5 m s^{-2}/the acceleration is halved
i acceleration is inversely proportional to mass

9 **a** gravitational potential energy
b unbalanced force is weight force

c kinetic energy
d because the ‘elastic force’ of the stretched rubber rope slows her down/also air friction will slow her down a small amount
e the ‘elastic force’ in the stretched rubber rope
f the more the rubber rope is stretched the larger the force in the rope
g no, because an unbalanced force is needed to make an object change direction
h gravitational potential energy to kinetic energy to elastic potential energy to kinetic energy to gravitational potential energy, etc.

10 a weight force: Fg = mass x g = 80 kg x 10 m s^{-2} = 800 N
b support force = 800 N acting upward from the road
c yes, because the bike is travelling at a constant speed on a level road
d thrust force = 60 N
e unbalanced forces, because the net force is not zero
f acceleration: a = F ÷ m = 160 N ÷ 80 kg = 2 m s^{-2}
g net force: F = m x a = 80 kg x 1.5 m s^{-2} = 120 N backwards
h weight = 800 N downward/support = 800 N upward/both thrust and friction forces are zero

11 a air friction or drag slows down the jet skier/friction between the underside of the ski and the water slows down the skier/friction helps the skier maintain his hand and feet grip
b air friction or drag will slow down sprinters/friction between soles of shoes and track will provide grip as they run
c air friction or drag will help by slowing down parachutist

Unit 23: Energy, Work And Power

1 a J **b** M **c** A **d** N
e G **f** R **g** L **h** B
i Q **j** C **k** F **l** D
m I **n** E **o** H **p** K
q P **r** O

2 a energy is defined as having the capacity to do work/work is done when a force moves an object
b kinetic energy is the type of energy possessed by a moving object/gravitational energy is the type of energy an object gains when it is lifted
c work is the transfer of energy by the application of a force/power is the rate at which work is done
d an independent variable causes a change in the dependent variable

3 The cyclist does no work because he is applying no force/the tug does no work because the ship does not move/the linesman does work because he is applying a force to lift his body and he moves up the pole.

4 a Work = force x distance = 80 N x 2000 m = 160 000 J
b Work = force x distance = 960 N x 9 m = 8640 J

5 a true **b** false – you do no work
c true
d false – depends on the size of the force and the distance the object is moved
e true **f** true **g** true
h false – does not depend on how long you take
i true **j** true **k** true

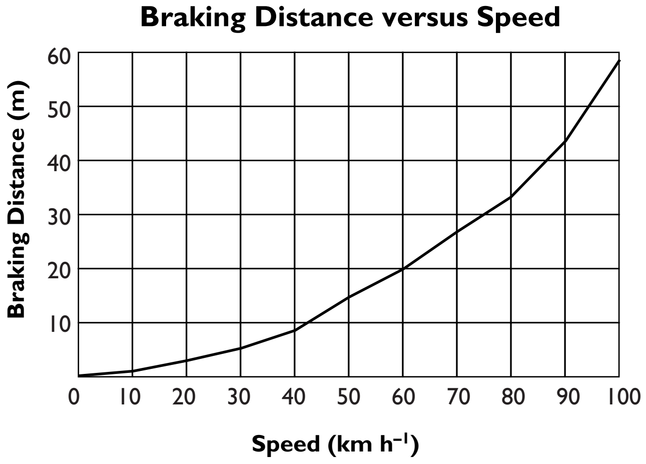
6 a If the force used is increased, then the work done will increase.
b If the distance an object is moved is increased, then the work done will increase.
c If the mass of an object is increased, then its kinetic energy will increase.
d If the speed of an object is increased, then its kinetic energy will increase rapidly.
e If the height of an object is increased, then its potential energy will increase.
f If the time taken to do work is increased, then power will decrease.

7 a yes, because a force is used and the bag moves upwards
b Work = force x distance = mass of bag x g x distance lifted
= 5 x 10 x 1 = 50 J
c gravitational potential energy
d 50 J, as gain in energy equals work done
e yes, because a force is being used and the trolley has moved
f Work = force x distance = 12 N x 15 m = 180 J
g kinetic energy
h 180 J, as gain in energy equals work done

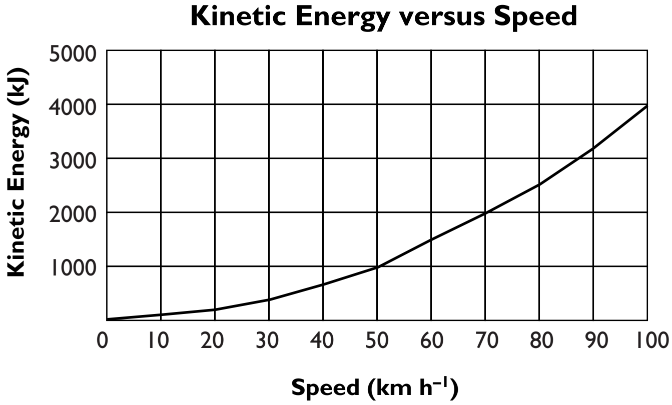
8 a straight line sloping upwards
b as the height of the box increases, its potential energy increases
c potential energy gain is proportional to height lifted
d curves downwards then levels off
e as time taken to do work increases, the power output decreases
f power is inversely proportional to time taken to do work
g rises rapidly
h as speed increases, the object's kinetic energy increases rapidly
i kinetic energy is proportional to the square of the object's speed

9 a the sum of the reaction and braking distances
b the time it takes you to spot the danger and apply the brakes
c reaction time and speed
d 56 m
e a force must be applied in the opposite direction to the car's motion to slow it down
f transformed into heat energy of the brakes and tyres
g power of the brakes/tyre tread/road surface/speed
h because you will have four times as much kinetic energy to get rid of
i 15 m x 4 = 60 m

10 a



b speed is the independent variable and braking distance is the dependent variable
c slopes upwards rapidly
d braking distance increases rapidly
e braking distance is proportional to the square of the speed
f



g because speed is the independent variable – the one that was altered in the investigation
h slopes upwards rapidly
i as speed increases, the car's kinetic energy increases rapidly
j kinetic energy is proportional to the square of the speed
k very similar-shaped curves
l as speed increases, both kinetic energy and breaking distance rise rapidly/both kinetic energy and breaking distance are proportional to the square of the object's speed

Unit 24: Waves

1 **a** medium **b** Electromagnetic **c** energy
d longitudinal **e** sound **f** transverse

2 **a** two **b** 5 cm **c** 15 cm
d two **e** one wave per second = 1Hz

3 **a** 0.36 m s^{-1} **b** 330 m s^{-1} **c** 330 000 Hz
d 30 m **e** 3 m

4 100 waves in 5 seconds = 20 waves in 1 second = 20 Hz

5 **a** 300 000 000 m s^{-1} = 3.0×10^8 m s^{-1} **b** 600 m

6 **a** Light waves/water waves/waves along a rope **b** sound waves
c wavelength **d** sound **e** louder
f higher (in pitch) **g** ultrasound

7 **a** the sound will have to travel 220 m. $t = d/v = 220$ m /330 m s^{-1} = 0.66 s.
b **i** 16.5 m
ii 0.165 m =16.5 cm

Glossary

Word/phrase	Meaning
Acceleration	The change in an object's speed (or direction) caused by unbalanced forces.
Accelerometer	An instrument used to measure instantaneous acceleration.
Acid	A substance that forms an acidic solution in water; substance that releases hydrogen ions in water.
Acid particles	Hydrogen ions.
Acid rain	Rainwater that has a pH of less than 7.
Acidic solution	A solution with a pH of less than 7.
Acquired variation	Differences between organisms caused by the environment or by experience.
Active transport	The pumping of nutrients into the plant root hairs by a process that uses energy.
Actual motion	The real motion of an object.
Aerobic	In the presence of oxygen.
Alcohol	A carbon compound with an OH group attached.
Alkali	A base that is soluble in water.
Alkaline solution	A solution with a pH greater than 7.
Alkanes	Hydrocarbon molecules that have single bonds only.
Alkenes	Hydrocarbon molecules with one double bond.
Alleles	Alternative forms of a gene.
Allotropes	Alternative forms of an element.
Alloying	Mixing other elements into a molten metal.
Ammeter	An instrument that measures the size of an electrical current.
Amorphous solids	Solids that do not have a crystalline structure.
Amp or ampere	Unit for current.
Amplitude	The distance between the top of a wave and the centre line.
Anaerobic	In the absence of oxygen.
Analog meter	A meter which has a scale and a marker.
Animal breed	A group of animals especially developed by artificial selection.
Antibiotic	A chemical produced by fungi that is used to kill bacteria.
Antibiotic resistance	Occurs when bacteria are no longer affected by an antibiotic.
Antibody	A chemical that recognises and helps destroy a pathogen.
Antigen	A marker chemical on a pathogen.
Antiseptic	A chemical applied to a wound to prevent infection.
Apparent motion	The illusion of motion by an object caused by the motion of the observer.
Artificial selection	Occurs when organisms with specific traits are selected and bred from over many generations.
Asexual reproduction	The production of identical offspring by a single parent.
Ash	The fine dust in the cloud produced by an eruption.
Astronomy	The study of the origin, nature and motion of heavenly bodies.
Atomic number	The number of protons in the nucleus of an atom.
Atoms	The basic building blocks of matter, extremely small particles that all matter is made of.
Average acceleration	The mean acceleration over a journey.
Average speed	The mean speed over a journey.
Axis	An imaginary line around which a spinning body turns.
Bacteria	Micro-organisms which do not have a cell nucleus.
Balanced equation	A chemical equation in which there are the same number of each type of atom on both sides.
Balanced forces	Occurs when two forces on an object are equal and opposite.
Base	A chemical that can neutralise an acidic solution.
Bases	The units of the genetic code.
Binary fission	Splitting into two organisms through cell division.

Glossary

Word/phrase	Meaning
Biological control	Using predators, parasites or pathogens to control pests.
Biological principle	A general principle about the functioning of all organisms.
Biomass	The amount of living matter in a defined area.
Biotechnology	Making use of micro-organisms for human ends.
Boiling point	The temperature at which a particular liquid boils into a gas.
Bond	The force of attraction that holds atoms together.
Breeding	Developing new strains of plants or animals through artificial selection.
Carbohydrate	A class of food molecules that provide energy.
Carnivore	An animal which eats other animals.
Catalyst	A chemical that speeds up the rate of a reaction without being used up itself.
Cell membrane	The surface that encloses a cell and controls the entry and exit of chemicals.
Cell nucleus	The control centre of a cell that also contains the chromosomes.
Cells	The basic building blocks of living things.
Change of state	Changing from a solid or liquid or gas state to a different state.
Charge	A property of particles that is either positive or negative.
Chemical bonding	The attraction that holds atoms in molecules or lattices.
Chemical cell	An object that transforms chemical energy into electricity, e.g. a battery.
Chemical plant	A factory that carries out commercial chemical reactions.
Chemical potential energy	The energy stored in the bonds that hold atoms together.
Chemical process	A series of chemical reactions carried out to make a particular commercial product.
Chemical properties	Properties that relate to how a substance reacts.
Chemical reaction	Occurs when new chemicals are formed from existing chemicals.
Chloroplast	An organelle in a plant cell that carries out photosynthesis.
Chromosome	A structure in the nucleus consisting of a long string of genes.
Circuit	A complete conducting pathway.
Cloning	Producing offspring which are genetically identical to a single parent organism.
Coal	Hard black sedimentary rock formed out of the remains of ancient swamp vegetation which has been compressed over millions of years.
Collisions	Occur when particles such as molecules and ions hit each other.
Combustion	The process of burning a substance; rapid oxidation of a substance.
Competition	Occurs when organisms living in the same location require the same resource, e.g. light, water.
Complete combustion	Occurs when a fuel or a substance is burnt in an abundant supply of oxygen.
Component	A part of an electrical circuit.
Compound	A chemical substance in which different types of atoms are bonded; a substance in which non-identical atoms are bonded.
Concentration	The number of particles per unit volume.
Conductor (electrical)	A substance that allows electricity to flow through it freely.
Conductor (thermal)	A substance that allows heat energy to travel through it freely.
Connective tissue	Cells that join parts of the body such as ligaments and tendons.
Constellation	A group of stars in a section of the night sky.
Consumer	Organism such as an animal that must eat other organisms in order to obtain energy and nutrients.
Contact force	Occurs when the object applying the force touches the other object.
Controlled variable	A variable that is kept constant.
Convection	The transfer of heat to another location through a current in a liquid or a gas.
Convection current	A current caused by a body of heated gas or liquid rising.

Glossary

Word/phrase	Meaning
Coulomb	The scientific unit for charge.
Covalent bond	Occurs when two atoms share electrons.
Cracking	The process of breaking long chain hydrocarbons into smaller more useful ones.
Crater	A depression created by a volcano or a meteorite.
Crop	A plant product which has been grown and harvested.
Crude oil	A mixture of oils found inside the earth's crust formed from the remains of ancient marine organisms buried under the sea floor over millions of years.
Crust	The solid outer layer of rock forming the earth's surface.
Crustal plate	An area of the earth on which the continents and ocean floor sit.
Crystalline solids	Solids made out of crystals.
Crystallise	Formation of crystals from molten rock or from a solution.
Crystals	Solid substances showing definite geometrical shapes.
Culturing	Growing micro-organisms on agar in a petri dish.
Current	A flow of charged particles such as electrons; a flow of electrical charge.
Current electricity	A flow of charged particles through a conductor.
Cytoplasm	The area inside the cell not including the nucleus.
Data	Either observations or measurements.
Deceleration	Occurs when the speed of an object is decreasing.
Decomposer	Organism such as a fungus which breaks down exposed food and dead bodies.
Decomposition	Occurs when a compound is split into simpler compounds.
Degrees celsius °C	The scientific unit in which temperature is measured.
Density	The mass of a specified volume of matter.
Dependent variable	A variable which alters because of a change in another.
Deposit	A layer of rock or mineral laid down over a long period of time.
Dermal tissue	Covering cells in plants.
Digestion	The breakdown of food molecules by enzymes.
Digestive enzymes	Chemicals produced by organisms which break down large food molecules.
Digital meter	A meter which provides the reading in digits.
Direct current, DC	A current which flows in one direction only.
Disinfectant	A chemical which kills micro-organisms.
Distance	Describes how far an object has travelled.
Distance-time graph	A graph on which the distance gone is plotted against the time elapsed.
DNA	The molecules which chromosomes are made out of.
Dominant gene	A gene which will always be expressed whether one or two are possessed by an organism.
Double helix	The shape which two DNA molecules form together.
Drag force	An opposing force created when an object passes through a body of water or air; a form of friction.
Ductile	Able to be stretched out into thin wires.
Economic return	The amount of income an enterprise generates.
Ecosystem	A community of living things that form a system through which energy flows and nutrients cycle.
Effector organ	A part of the body, such as a muscle, that performs an action when it receives a nerve impulse.
Egg	An immobile female gamete, which is much larger than a sperm.
Elastic potential energy	The energy which is stored in stretched or squashed objects.
Electrical charge	A property of objects which can be either positive or negative.
Electrical conductor	A substance which allows a current to flow through it.
Electrical energy	The energy carried by charged particles travelling in a current.
Electrical force field	The force which drives a current around a circuit.

Glossary

Word/phrase	Meaning
Electricity	A form of energy associated with charged particles.
Electron cloud	The space around the nucleus that all electrons of an atom occupy.
Electron shell	The space around the nucleus that electrons with equal energy occupy.
Electrons	Extremely small negative particles which fly around the nucleus; negatively charged particles which flow in a current.
Element	A substance made of identical atoms; a pure substance made of only one type of atom.
Elliptical orbit	The oval-shaped orbit of a satellite.
Embryo	An early stage of an organism's development when organs are recognisable.
Endocrine system	The glands which secrete hormones into the blood.
Energy	Defined as the capacity to do work; something required to order to do work.
Energy efficiency	The percentage of input energy which becomes useful energy.
Energy input	The energy supplied in an energy transformation.
Energy output	The energy produced in an energy transformation.
Energy pyramid	A diagram showing the flow of energy through an ecosystem.
Energy transfer	Occurs when the type of energy passed on remains the same.
Energy transformation	Occurs when the type of energy passed on is a new form.
Environmental factors	Aspects of an organism's surroundings which affect its functioning.
Environmental impact	The consequences of an enterprise upon the physical environment or other species.
Environmental issues	Issues related to the use or abuse of the environment.
Enzymes	Catalysts produced by living organisms.
Equator	An imaginary circle around Earth at an equal distance from both poles.
Equilibrium	When balanced forces act on an object.
Epithelial tissue	Covering cells in animals such as skin.
Ethical issues	Issues related to the treatment of humans and other animals.
Evolution	The modification of a species over a long period of time or the formation of a new species.
Excretion	Disposal of wastes from cells by an organism.
Expansion	An increase in the size of an object.
Extracellular digestion	Digesting food outside of the body of the organism by secreting enzymes onto food.
Fermentation	The conversion of sugar into alcohol (ethanol) and carbon dioxide by yeast.
Fertilisation	The fusion of a sperm with an egg resulting in a zygote.
Flaccid	Description of a cell that does not have enough water and becomes floppy.
Flora and fauna	The collection of plant and animal species present.
Food	Complex molecules which supply energy and nutrients to organisms.
Force	Required to change the motion or shape of an object; a push or a pull.
Formula	A mathematical relationship between different quantities.
Formula equation	A way of summarising a chemical reaction using the formulae of the chemicals involved.
Fossil fuel	Fuels such as oil and gas which have been naturally formed from the remains of plants and animals that lived millions of years ago.
Fossil record	The distribution of fossils in different rock strata.
Fossils	The remains or impressions of ancient organisms.
Fractional distillation	A process for separating a mixture of liquids using their different boiling points.
Free electrons	Electrons which can wander from atom to atom in a metal.
Frequency	The number of complete waves passing a point each second.
Friction	A force caused by two surfaces rubbing against each other which produces heat.
Fuel	A substance which is burnt to release heat energy.
Fungi	A group of immobile organisms that feed on dead or living organisms and exposed food.

Glossary

Word/phrase	Meaning
Gametes	Special cells (egg and sperm) involved in sexual reproduction; special cells used to combine genes from two organisms.
Gene	An inherited object that is involved in determining the appearance of a trait.
Genetic code	The code in which genetic information is written along DNA molecules.
Genetic engineering	The modification of the genes of other organisms by humans.
Genetics	The study of how genes are inherited and expressed.
Genome	The total collection of genes possessed by an organism.
Genotype	The two genes an organism possesses for a trait.
Geological period	An interval of Earth's history with a unique fossil flora and fauna.
Geology	The study of Earth's structure and its rocks.
Geostationary orbit	An orbit in which a satellite stays above the same point on Earth's surface.
Global temperature	The average annual temperature over the entire globe.
Global warming	A gradual increase in the average global temperature.
Gradient	The slope of a graph line.
Gravitational potential energy	The energy stored in an object held above the ground; the type of energy an object gains when lifted.
Grazing	Eating plant tissue such as leaves and grass.
Ground tissue	The cells that make up the main part of a plant.
Group	A column of the Periodic Table.
Habitat	The type of environment in which a species lives.
Health impact	The effect of an enterprise on the health of workers or on members of the local community.
Heat conduction	The transfer of heat energy from atom to atom in solids.
Heat energy	A form of energy transferred from a hot to a colder object.
Heavenly body	A large mass located in space.
Hemispheres	The two halves of the planet above and below the equator.
Herbivore	An animal which eats plant material only.
Heterozygous	Occurs when the two genes an organism possesses for a trait are different.
Homeostasis	The process of keeping internal body conditions constant.
Homologous chromosomes	A pair of similar-shaped chromosomes, one of which came from each parent.
Homozygous	Occurs when the two genes an organism possesses for a trait are identical.
Homozygous dominant	Occurs when an organism has two dominant genes for a trait in its genotype.
Homozygous recessive	Occurs when an organism has two recessive genes for a trait in its genotype.
Hot spot	An area of weakness in the earth crust that forms a volcano that is carried along as the crust moves.
Hydrocarbon	A compound made of carbon and hydrogen atoms only.
Hydroponics	Growing plants in a nutrient-rich solution without any soil.
Hyphae	The fine threads of a fungus that invade a host.
Hypothesis	A statement that can be tested experimentally.
Igneous rocks	Rocks formed when magma solidifies.
Illumination	The shining of light on an object.
Immune system	The parts of the body that protect it from disease.
Immunity	The ability to prevent an infection occurring.
Impermeable	Something that will not allow liquid to pass through.
Incomplete combustion	Occurs when a fuel or substance is burnt in limited oxygen.
Independent variable	The variable that causes a change in another variable; the variable that is altered regularly.

Glossary

Word/phrase	Meaning
Infection	A growth of harmful micro-organisms in or on an organism.
Inherited variation	Differences between organisms determined by the genes inherited at conception.
Inoculate	To introduce micro-organisms onto an agar medium in order to grow them.
Instantaneous acceleration	The acceleration of an object at one point in time.
Instantaneous speed	The speed of an object at one point in time.
Insulator (electrical)	A substance that does not allow a current to flow through it.
Insulator (thermal)	A substance that does not allow heat to pass along it.
Inversely proportional	Doubling one variable, say, causes the other to be halved.
Ion	A charged atom or group of atoms.
Ionic bonding	The attraction between oppositely charged ions.
Ionic compound	A substance in which atoms are held together by ionic bonds.
Iron sand	Black sand which is rich in the ore magnetite.
Joule	The scientific unit for energy; work done when a one newton force moves an object a distance of one metre.
Keyword	A word or phrase used in searching for information.
Kilogram	The scientific unit for mass.
Kilojoule	Equal to 1000 joules.
Kinetic energy	The energy possessed by a moving object.
Lattice	A regular array of billions of atoms or ions.
Lava	The molten rock that flows out of a volcano.
Law of Energy Conservation	Energy cannot be created or destroyed, only transformed from one form to another.
Lignin	Material that forms wood in plants.
Limestone	A sedimentary rock formed from the shells of marine creatures accumulated in layers on the sea floor over millions of years.
Limiting factor	An environmental factor that is outside the conditions that a species can tolerate.
Lipids	A class of food molecules that are rich in energy, includes fats and oils.
Litmus	A chemical that turns red in acid and blue in alkali.
Longitudinal wave	A wave in which the vibration is in the direction of travel.
Lunar cycle	The period of time from full moon to full moon.
Lunar eclipse	Occurs when the Moon moves into Earth's shadow.
Lustre	The degree of shine on the surface of a solid.
Lymph nodes	Small lumps containing billions of white blood cells that fight bacteria in the body.
Lymphocytes	White blood cells that produce antibodies to attack pathogens.
Magma	Hot molten rock from underneath the crust.
Magnetic	A property that causes an object to affect a nearby compass needle.
Magnetite	A mineral rich in iron oxide, found in black iron sand.
Magnitude	The size or strength of a quantity such as force.
Malleable	Able to be hammered or squashed into a new shape.
Mantle	The deep layer of semi-molten rock underneath the crust.
Mass	The amount of matter in an object; a large body.
Mass extinction	Occurs when a large number of species become extinct at the same time.
Mass number	The number of protons and neutrons in the nucleus of an atom.
Matter	All the substances in the universe.
Mean	The average of a set of measurements.
Medium	The material – such as water or air – through which a wave passes.

Glossary

Word/phrase	Meaning
Medium (biology)	A nutrient-rich substance used to grow micro-organisms such as fungi and bacteria.
Medium (physics)	A substance needed for some forms of energy transfer.
Meiosis	A type of cell division that produces four gametes each with only half the normal number of chromosomes, each gamete having a different set of chromosomes.
Melting point	The temperature at which a particular solid melts into a liquid.
Mesophyll	The tissue in plant leaves that contains chlorophyll.
Metal carbonate	A compound made of metal ions bonded to carbonate ions.
Metal compounds	Chemicals in which metal ions are bonded to negative ions.
Metal hydrogen carbonate	A metal compound containing bicarbonate ions (HCO^{3-}) bonded to metal ions.
Metal hydroxide	A compound with metal ions bonded to hydroxide ions.
Metal oxide	A compound in which metal ions are bonded to oxide ions.
Metallic bonding	The attraction between metal atoms and free electrons.
Metals	Shiny solids that are good conductors of heat and electricity.
Metamorphic rock	Rock that has been transformed under high temperature and pressure.
Meteorite	A rock from space that collides with Earth's crust, large ones can cause craters.
Micro-organisms	Very small organisms visible under the microscope.
Mineral	A naturally occurring, non-living substance with a definite composition and structure.
Mineral exploration	Surveying and prospecting to locate new mineral veins or seams.
Mineral extraction	The removal of a mineral resource from Earth's crust.
Mining	The process of extracting useful minerals from Earth's crust.
Mitochondria	Organelles in cells that can release energy from glucose.
Mitosis	A type of cell division that results in two cells, each with an identical set of chromosomes.
Molecular compound	A group of non-identical atoms sharing electrons.
Molecule	A group of atoms bonded together because they are sharing electrons.
Molten	In a liquid state due to being heated to high temperatures.
Momentum	The capacity of a moving object to keep on moving.
Monohybrid cross	The pattern associated with the inheritance of a single trait.
Motion	The act of moving from one location to another.
Motor neurone	A nerve cell that carries a message from the brain to a muscle or gland.
Mountain building	The crumpling up of Earth's crust when tectonic plates slowly collide over millions of years.
Natural gas	A mixture of gases found in Earth's crust formed out of the compressed remains of ancient plants and animals over a period of millions of years.
Negative ion	An atom that has more electrons than protons.
Nervous system	A series of fibres running through the body that carry messages in the form of an electrical impulse.
Net force	The overall effect of combining the forces acting on an object.
Neurone	Nerve cell.
Neutral (chemical)	A solution that is neither acidic nor alkaline; a solution with a pH of 7.
Neutral (electrical)	Particles that are uncharged or have no overall charge.
Neutral atom	An atom with equal numbers of protons and electrons.
Neutralisation	A reaction in which a neutral solution is formed.
Neutralise	To make neither acidic nor alkaline.
Neutrons	Uncharged particles in the nucleus of an atom.
Newton	The scientific unit for force.
Non-contact force	The object applying the force does not need to touch another object in order to act on it.
Non-metals	Elements which do not have metallic properties.
Nucleus (atomic)	The central area of an atom containing protons and neutrons.

Glossary

Word/phrase	Meaning
Nucleus (cell)	Structure within a cell that contains the chromosomes.
Numerical data	Data that is in the form of numbers.
Nutrient	A substance used by a living thing as food.
Nutrients	Chemicals required by living organisms for growth and the maintenance of life.
Nutrition	The manufacturing or processing of food by organisms.
Ohm	The scientific unit of resistance.
Ohm's Law	States that the voltage across a component is proportional to the current flowing through it, provided the temperature of the component remains constant.
Opaque	Does not allow light to pass through.
Optimal growth	The best possible growth of organisms which occurs when all environmental factors are within their optimal ranges.
Optimal range	The range of values for one particular environmental factor that gives the best growth rate.
Ore	A mineral or a combination of minerals found in a deposit in the crust.
Organism	An individual living thing.
Oscillation	See vibration.
Osmosis	A form of diffusion in which water moves through a semi-permeable membrane from an area of lower solute concentration to an area of higher solute concentration.
Oxidation	A reaction in which oxygen atoms bond with other atoms; a reaction in which atoms lose electrons.
Parallel circuit	A circuit in which components are connected in several branches.
Parasitism	Occurs when one organism lives in or on a larger organism, feeding off it but not killing it.
Pathogen	A disease-causing micro-organism.
Peat	Material from plants that has been buried in swampy ground then squashed by layers of sediment. An early stage of becoming coal.
Pedigree chart	A technique used to identify the genotypes of offspring or parents.
Period	A row of elements across the Periodic Table.
Periodic Table	A chart with the chemical elements arranged in periods and groups.
Petroleum	Crude oil formed underground from the remains of marine creatures buried millions of years ago then transformed under heat and pressure.
PH scale	The scale used to indicate acidity or alkalinity of a solution.
Phagocytes	White blood cells which engulf pathogens.
Phases of the Moon	The appearance of the Moon during stages of the lunar cycle.
Phenomena	Measurable or observable events.
Phenotype	The appearance of a trait.
Phloem	Tissue that carries sugars around plants.
Photochemical smog	Smog formed in sunlight from car exhaust fumes.
Photosynthesis	A process occurring in leaves that transforms carbon dioxide and water into sugar using sunlight energy.
Physical properties	Properties of substances that do not involve chemical reactions.
Pitch	A description of a sound based on its frequency.
Placers	Sand or gravel deposits containing a particular mineral, e.g. gold.
Planet	A large heavenly body that orbits a star such as the Sun.
Plankton	Microscopic animals and plants that live in the sea.
Plant variety	The result of generations of breeding involving the selection of plants with desirable features.
Plate boundary	The junction between neighbouring tectonic plates of Earth's crust.
Plutonic (intrusive) igneous rock	The rock formed when magma solidifies inside the crust.
Pollen	Microscopic grains produced by flowers containing sperm.
Pollination	The act of transferring pollen from male to female organs in flowers.

Glossary

Word/phrase	Meaning
Pollutant	A solid, liquid or gas released into the environment that has an adverse effect.
Polyatomic ion	Ions made of several atoms that are involved in sharing electrons.
Polymerisation	Occurs when small molecules are joined into long chains in special chemical reactions.
Positive ion	An atom that has more protons than electrons.
Potential energy	Energy that is stored in some way.
Power	The rate at which energy is supplied or used; the rate at which work is done.
Power rating	The wattage of a component.
Primary body	The larger body around which a satellite orbits.
Primary data	Scientific data collected by oneself.
Producer	Organism such as a plant that is able to make complex food molecules using simple molecules and ions from its environment.
Products	The new substances formed in a chemical reaction.
Proportional	Means that, for example, the doubling of one variable will cause the other to double as well.
Proportional to the square	Means that one variable increases in proportion to the square of the other.
Proteins	A food class needed for growth and health; genes are expressed through proteins.
Protons	Particles with a positive charge found in the nucleus of an atom.
Protoplanet	An early stage in the formation of a planet.
Punnet square	A technique used to predict the expected ratio of phenotypes amongst offspring.
Pure breeding	Organisms that produce offspring that resemble them in regard to a particular trait.
Quantity	An amount of something that is measurable.
Quarantine	The isolation of a person or animal with a serious infectious disease.
Quarrying	Activity in which a mineral resource is dug, cut or blasted out of the landscape.
Radiant heat	The transfer of heat by infra-red waves.
Radiation	The transfer of energy by electromagnetic waves e.g. light, radio waves, X-rays.
Radioactive decay	Occurs when atoms break down into smaller atoms releasing radioactivity.
Radiometric dating	The dating of rocks by measuring the ratio of parent atoms to the daughter atoms produced by radioactive decay.
Rate	How fast something is done.
Reactants	The original substances supplied in a reaction.
Reaction	Occurs when existing chemicals are transformed into new chemicals.
Reaction force	The equal but opposite direction force that occurs automatically when a force is applied to an object.
Reaction rate	The speed at which reactants are changed into products.
Reaction rate curve	A graph showing the rate at which a product is formed in a chemical reaction.
Reactivity series	A list of different metals arranged according to the strength of their reactions with oxygen, water and acids.
Recessive gene	A gene that is only expressed if the organism possesses two in their genotype.
Reflex arc	A nerve pathway that produces an automatic response when stimulated.
Relative density	The mass of an object compared to the mass of a similar volume of water.
Relay neurone	A nerve cell that links a sensory neurone with a motor neurone in the central nervous system.
Replication	The production of multiple copies of a virus/the production of two identical DNA molecules.
Reproduction	The process of making of new organisms.
Resistance	The opposition to the flow of electrons through a substance.
Resistor	An object that opposes the flow of current; a component that is designed to limit current flow.
Resource competition	Occurs when organisms living in the same location require the same resource, e.g. light.
Respiration	The release of energy from glucose molecules that occurs within cells.

Glossary

Word/phrase	Meaning
Retrograde motion	The apparent reversal in the direction of motion of some planets.
Rheostat	An object whose resistance can be varied.
Rock	The solid material that forms the bulk of Earth's crust.
Rock cycle	The transformation of rock into different forms, e.g. magma, igneous, sedimentary, metamorphic.
Rock strata	Layers of rock containing different minerals and perhaps fossils.
Root hair	Small roots through which water and nutrients enter the plant.
Rounding off	Reducing a figure to a certain number of decimal places.
Salt	The solid chemical left after an acid has been neutralised by a base and the water evaporated.
Sampling	Measuring a randomly selected but representative subset of the objects being studied.
Saprophytes	Organisms that feed on dead organisms, e.g. some bacteria and fungi.
Satellite	An object that orbits a larger primary body.
Science	The systematic investigation of phenomena using scientific methods/ the body of knowledge that results.
Scientific method	A way of collecting data that ensures the results are objective, reliable and valid.
Seams	Flat deposits of an ore or mineral.
Sediment	Rock fragments, sand, mud and the remains of organisms that settle onto the sea floor in layers.
Sedimentary rock	The rock formed when sediment on the sea floor hardens under the weight of material above.
Seismic activity	Earthquakes and tsunami.
Selective breeding	Organisms with desirable traits are selected in each generation and used to breed from.
Self-replication	The ability of DNA to make identical copies in the context of a cell.
Sensory neurone	A nerve cell that carries a message from a sense organ to the brain.
Series circuit	A circuit in which all the components are in the same loop.
Sexual reproduction	The production of varying offspring by gametes from two parents combining.
Smelting	The extraction of a metal from its ore by heating the ore with certain chemicals.
Solar cell	An object that transforms light energy into electricity.
Solar eclipse	Occurs when the Moon moves between the Sun and Earth.
Solar energy	The radiant energy generated by the Sun, which includes light, infra-red, and ultra-violet radiation.
Solar System	The Sun and its nine planets along with their moons.
Solidify	To change from a molten to a solid state.
Solubility	The amount of a substance that will dissolve in a specified volume of a particular liquid.
Sound energy	Energy that is transferred in waves by the compression and expansion of air.
Source research	Research that involves finding information from a range of sources.
South celestial pole	The point in the sky directly above the South Pole.
Species	A group of similar organisms able to produce fertile offspring.
Specific heat capacity	The heat needed to cause a 1°C rise in the temperature of 1 kg of a substance.
Speed	Describes how fast an object is travelling.
Speed-time graph	A graph on which the current speed is plotted against the time elapsed.
Sperm	Small, mobile male gametes.
Sporangium	The part of a fungi that produces spores.
Spores	Tough-walled resistant reproductive cells involved in dispersal.
Stable atoms	Atoms which have full electron shells.
Star	A gigantic glowing ball of gas, e.g. the Sun.
Stimulus	An action that starts an impulse in a neurone.
Stomata	Small opening on the underside of plants.
Strata	Layers of rock, particularly sedimentary layers.
Stratigraphic column	The sequence of strata found in a rock face from the youngest to the oldest.

Glossary

Word/phrase	Meaning
Structural formula	A diagram that shows how atoms in a molecule are bonded together.
Subatomic particles	Includes protons, neutrons and electrons.
Subduction	Occurs when one tectonic plate is forced under another.
Support force	The force that a surface applies to an object resting on it.
Synapse	The small gap between nerve cells.
Tarnishing	The slow oxidation of a metal in air.
Technology	The results of applying scientific knowledge in the design of useful objects or techniques.
Tectonic plates	The huge, slowly moving plates that Earth's crust is broken up into.
Temperature	A measure of the average kinetic energy of the particles making up a substance.
Terminal	A connection point on an electrical component.
Thermal conductor	An object that conducts heat energy well.
Thermal insulator	An object that is a poor conductor of heat energy.
Thermoregulation	The process the body uses to maintain a steady temperature.
Thrust force	The force that acts on an object making it move.
Time	Describes how long a journey or event has taken.
Total energy	The energy used by an object over a period of time.
Toxic	Poisonous or harmful to living things.
Toxin	A chemical produced by a pathogen that may poison cells.
Trait	A feature whose appearance is determined by genes.
Translucent	Light passes through but not clearly.
Transparent	Light passes through clearly.
Transpiration	The loss of water through the leaves of a plant.
Transverse wave	A wave in which the vibration is at right angles to the direction in which the wave is travelling, e.g. a water wave.
Trophic level	A feeding level in a food chain or energy pyramid.
Turgid	Description of a cell that is pumped up tight with water.
Unbalanced forces	Occurs when the net force on an object is not equal to zero.
Units	What physical quantities are measured in.
Universal indicator	A chemical used to show the pH of a liquid by a change of colour.
Useful energy	Energy that is able to be utilised in some way.
Vaccination	An injection with dead or weakened micro-organisms to provide immunity.
Vacuole	Storage area inside a cell.
Vacuum	A space in which there are no particles of matter.
Valence electrons	Electrons in the outer, occupied shell of an atom.
Variable	Something that varies in magnitude (size).
Vascular tissue	The cells that help transport materials around a plant.
Vein (mineral)	Mineral deposits that run through strata.
Vibration	The movement of a solid around a central position.
Viruses	Non-living objects that use cells to make copies.
Volcanic (extrusive) igneous rock	Rock formed when magma solidifies on or near the surface of the crust.
Volt	The unit for voltage gain or loss.
Voltage	The energy gained or lost as the current passes through a component.
Voltage gain	The potential energy provided by a power supply.
Voltage loss	The potential energy used by a component.
Voltmeter	A meter used to measure voltage gain or loss.

Glossary

Word/phrase	Meaning
Waste energy	The output energy which cannot be used.
Watt	The scientific unit of power; one joule of work being done each second.
Wattage	Another term for power rating.
Wavelength	The distance between one wave crest and the next.
Weathering	The gradual breaking down and wearing away of exposed rock.
Weight (force)	The force of gravity acting on an object.
Word equation	Describing a reaction using the names of chemicals.
Work	Something done when a force moves an object.
Xylem	Water conducting tissue in plants.
Zygote	The first cell of an organism after a sperm fertilises an egg; first cell of a new organism in sexual reproduction.

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