PASCALE WARNANT | PAUL ARENA | KAHNI BURROWS
GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA CORE SCIENCE STAGE 5

NSW AUSTRALIAN CURRICULUM SCIENCE | SECOND EDITION

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All activities have been written with the safety of both teacher and student in mind. Some, however, involve physical activity or the use of equipment or tools. **All due care should be taken when performing such activities**. Neither the publisher nor the authors can accept responsibility for any injury that may be sustained when completing activities described in this textbook.

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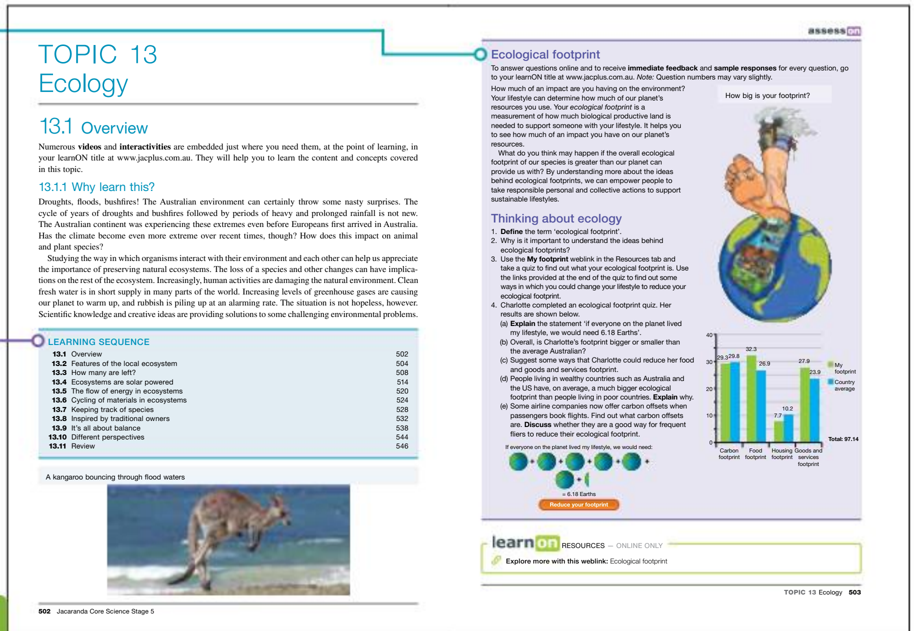
ABOUT THIS BOOK

The *Core Science Stage 5* textbook and learnON are designed for students who come to the science classroom with a range of interests, backgrounds and learning styles. The topic units provide an in-depth coverage of essential and additional syllabus content.

Each unit provides a range of investigations, stimulus material and activities to engage and challenge students, as outlined in this summary of Core Science features.

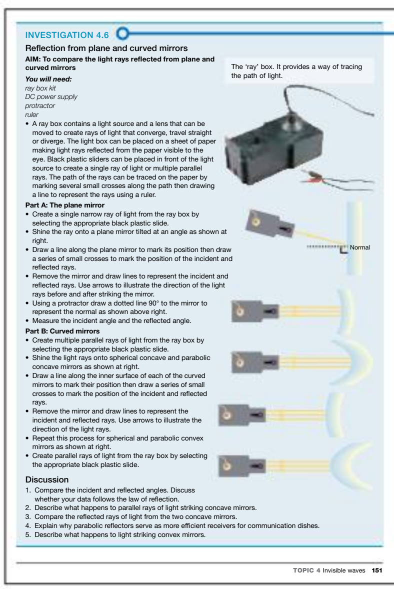
Chapter opening activities and investigations can be used to:
- show connections between science and students' own experiences
- provide opportunities for students to demonstrate their current thinking on topic concepts.

Thought-provoking chapter openings, including a summary of the key content covered in each unit



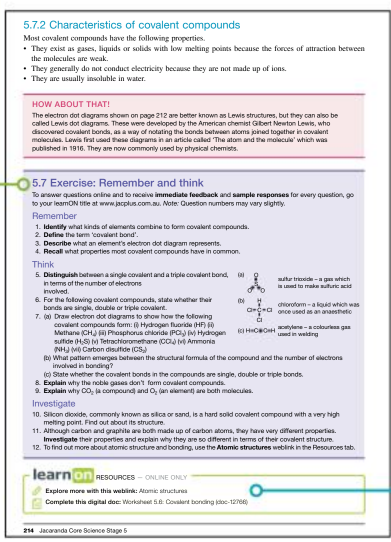
Activities at the end of each unit cover a full range of lower to higher order activities, including learnON interactivities.

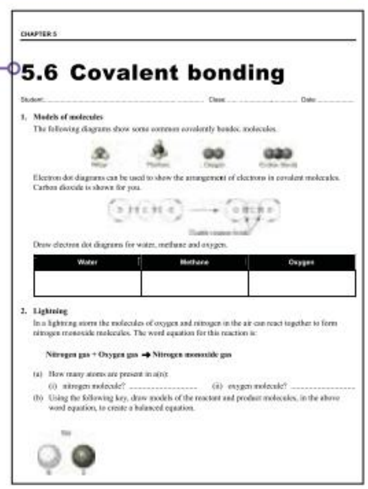
The black bolded words in questions highlight use of the key verbs that are applied in NESA exam questions. These questions give students some practice in answering this style of question, using the key words most relevant to stage 5 students.



Investigations in each chapter reinforce the topic concepts and provide a comprehensive practical program for stage 5 students. Investigations are placed in context, to help students relate their practical work findings to topic concepts.

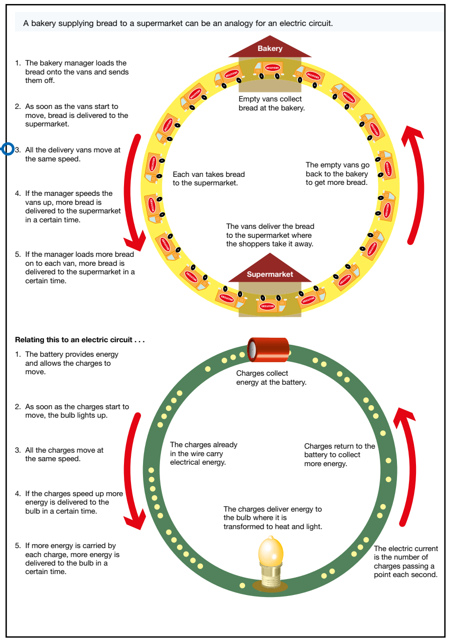
Accompanying worksheets can be found in the student learnON as Word files.

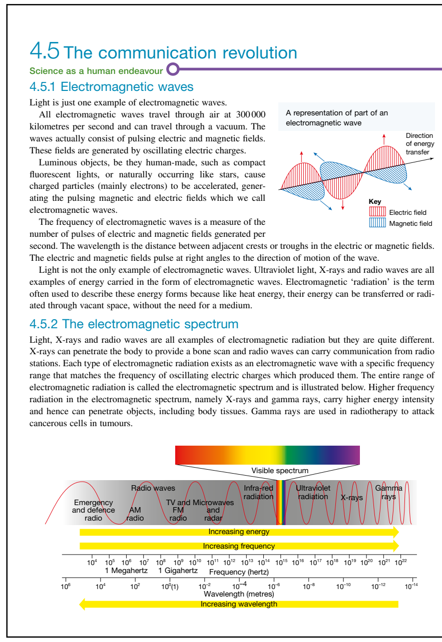




Units include descriptions of eLessons, interactivities and weblink-based activities available in Resources tab.

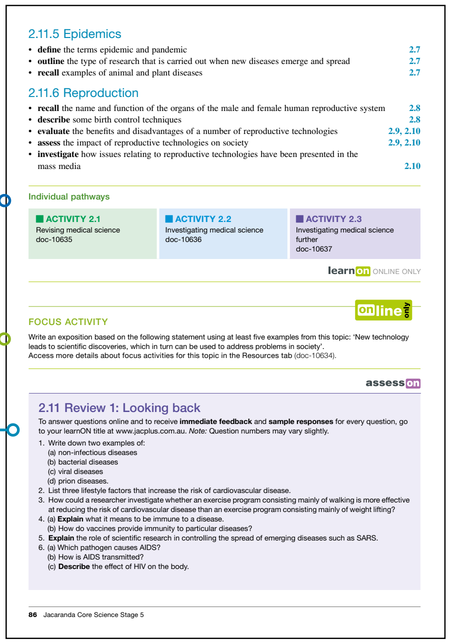
Concepts are explored through visually stimulating and detailed diagrams that engage visual and linguistic learners.

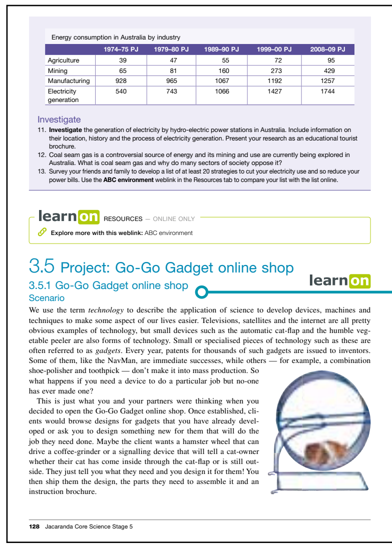




Science as a human endeavour units in each chapter provide high-interest content that explicitly links particular areas of the NSW Australian curriculum Science syllabus.

Individual pathways chapter revision Word documents at three differentiated levels.





ProjectsPLUS Some topics include a Project, resources for this can be found in the Resources tab.

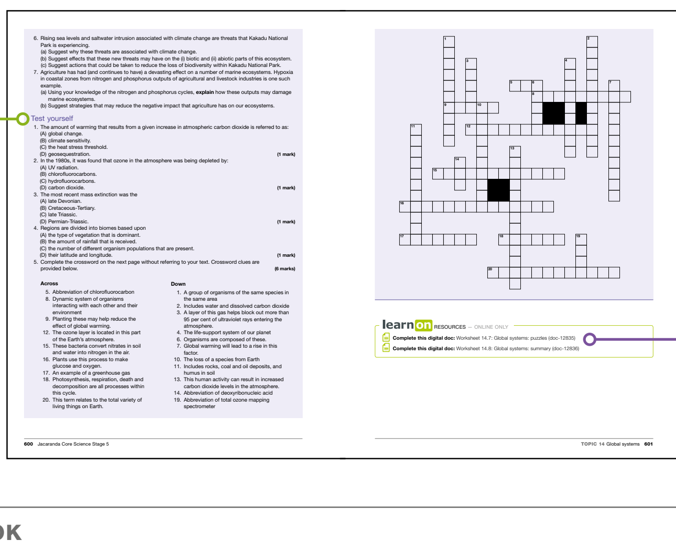
Focus activities provide revision for each chapter.

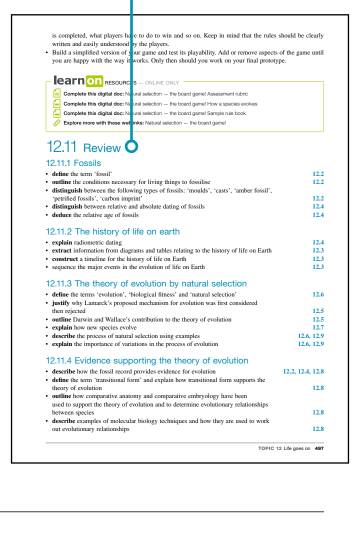
Looking back spreads provide a range of chapter review activities.

Puzzle and summary worksheets can be found in the student resources as Word files.

Study checklist gives students a detailed outline of the key content covered in the chapter.

Test yourself multiple choice and extended response questions are included at the end of each chapter.





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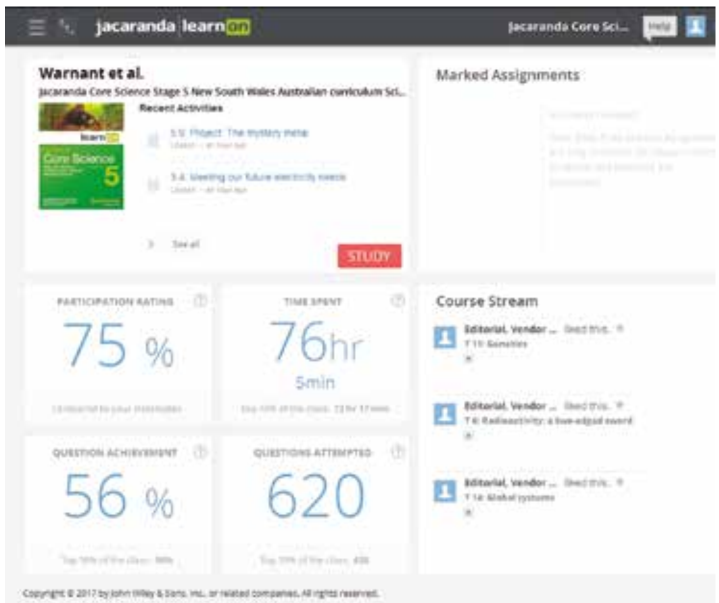
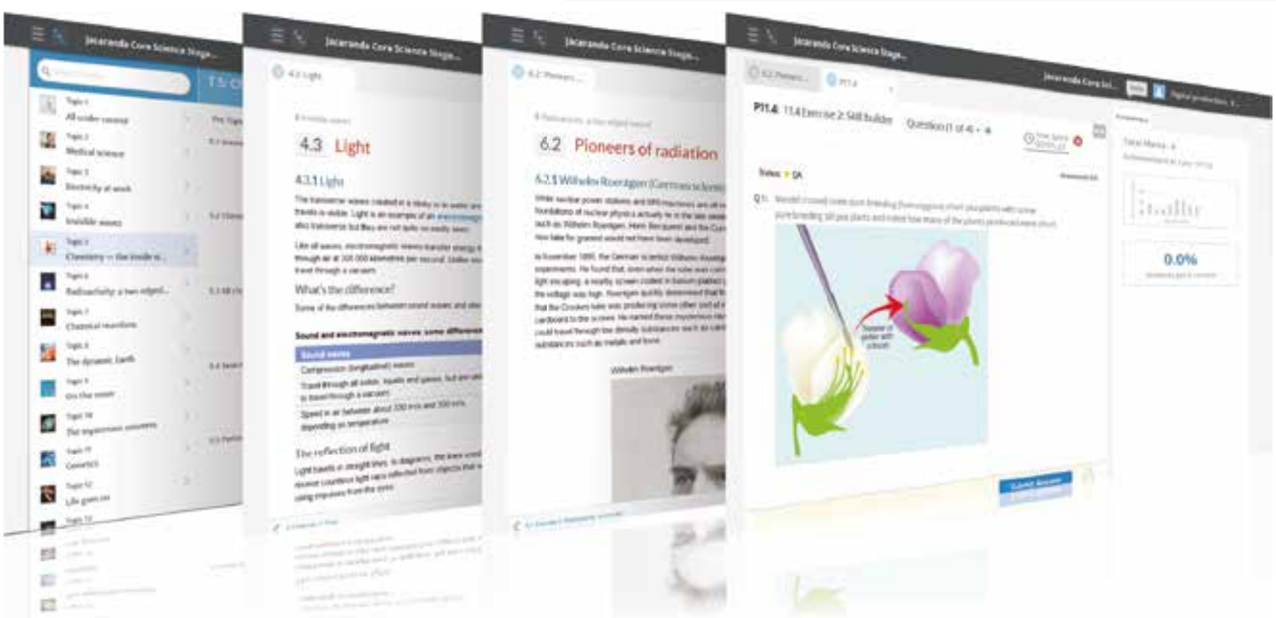
Core Science contains a free activation code for *learnON* (please see instructions on the inside front cover), so students and teachers can take advantage of the benefits of both print and digital, and see how *learnON* enhances their digital learning and teaching journey.

learnON includes:

- Students and teachers connected in a class group
- Hundreds of videos and interactivities to bring concepts to life
- Fully worked solutions to every question
- Immediate feedback for students
- Immediate insight into student progress and performance for teachers
- Dashboards to track progress
- Collaboration in real time through class discussions
- Comprehensive summaries for each topic
- Dynamic interactivities help students engage with and work through challenging concepts.
- Formative and summative assessments
- And much more …





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TOPIC 1
All under control

1.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

1.1.1 Why learn this?

How does this gymnast keep her balance? Receptors throughout her body provide her brain with information. Pressure receptors in the skin of her palms and the sides of her feet provide information about the position of the beam under her hands and feet. Light receptors in her eye provide visual information. Even receptors in her ears provide information that will help keep her balanced. Sensory nerves carry the information to the central nervous system. The brain processes it. When she is ready to complete her move, nerve cells in the gymnast's brain will fire impulses that will cause some muscles to contract and others to relax so that she will execute her move perfectly.

In this topic you will learn about two body systems — the nervous system and endocrine system — and the role they play in controlling and coordinating many of the processes that occur in the body to keep cells alive.

This gymnast's nervous system is coordinating the action of her muscles to keep her balanced.

LEARNING SEQUENCE

INVESTIGATION 1.1

Measuring reaction time

AIM: To compare 2 methods for measuring reaction time

You will need:

a stopwatch

access to a computer or tablet connected to the internet

- Use each of the following methods to measure the average reaction time of students in your class.

Method 1:

– All the students in the class need to organise themselves into a single line around the classroom and hold hands. The first student in the line needs to hold the stopwatch.

– When the teacher calls out 'start' the first student starts the stopwatch and squeezes the hand of the student next to them. That student in turn squeezes the hand of the next student until the end of the line is reached, then the hand squeeze needs to travel back down the line. When the first student feels the squeeze he or she stops the timer.

– Repeat 5 times and calculate the average time taken for the squeeze to travel up and down the line.

– The average reaction time for students in the class can be calculated using the formula:

$$\text{reaction time} = \frac{\text{average time for sqeeze to travel up and down the line}}{2 \times \text{number of students}}$$

Method 2:

– Use the **Reaction testing 1** and **Reaction testing 2** weblinks in the Resources tab to measure your reaction time.

– Enter each student's reaction time into a Google Docs spreadsheet (or write them on the board if you do not have access to Google Docs) and calculate the average reaction time for students in your class.

Discussion

1. Compare the results obtained by each method.
2. Which method is most valid? Justify your answer.
3. How could the reliability of each method be improved?
4. Which method gives the most precise measurement? Explain your answer.
5. What are some other ways that reaction time could be measured?

1.1 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. List some organs of the body that detect changes in your surroundings.
2. Which body systems relay messages from one part of the body to another?
3. **Explain** why it is important for the systems of the body to work together in a coordinated fashion.
4. Give examples of situations where it is important to respond quickly.
5. Give examples of situations where a slower and carefully considered response is important.

learnon RESOURCES — ONLINE ONLY

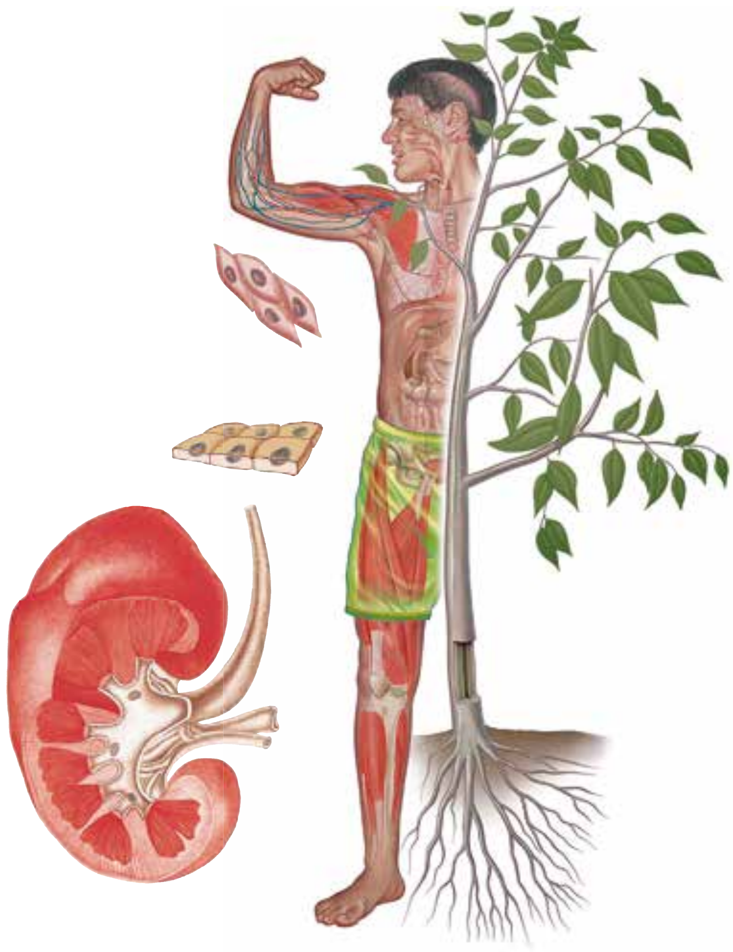
Explore more with this weblink: Reaction testing 1

Explore more with this weblink: Reaction testing 2

1.2 Systems keeping cells alive

1.2.1 Systems

The human body is made up of trillions of cells. Each of these cells must be supplied with nutrients and oxygen and produces waste products that need to be removed. Cells have other requirements as well. They function best within a narrow range of conditions including temperature, pH level and salt concentration. Body systems work together to keep cells alive.



Cells

All living things are made up of at least one cell. In **multicellular** organisms such as humans there are different types of cells. Each type of cell has a specific function or job. Red blood cells carry oxygen to all parts of the body. They are very small to fit through tiny blood vessels.

The longest cells in the body are nerve cells. Some nerve cells have a very long tail called an axon that allows them to relay messages from one part of the body to another.

Tissues

A group of similar cells that carry out a particular function together form a tissue. For example, the muscles of your arm contain different types of tissue including skeletal muscle tissue. Skeletal muscle tissue is made up of skeletal muscle cells.

Organs

Your heart, lungs, pancreas and kidneys are organs. Organs consist of different types of tissues. For example, the heart is made up of a number of types of tissues including cardiac muscle tissue and connective tissue.

Systems

Organs form parts of systems. The kidney is an organ of the excretory system. The heart is an organ of the circulatory system and the brain belongs to the nervous system. Systems in turn must work together to keep the organism alive.

1.2.2 The respiratory and circulatory system work together to supply cells with oxygen

All cells need oxygen. Air, containing oxygen, enters the respiratory system through the mouth or nose. It travels through the trachea, bronchi and bronchioles of the respiratory system and enters the **alveoli** (air sacs) of the lungs. There the oxygen diffuses into the bloodstream and binds to haemoglobin in red blood cells. It has thus entered the circulatory system. It will travel to the heart in the pulmonary vein and is then pumped out into the aorta, the main artery leaving the heart. The aorta splits into smaller blood vessels, which in turn branch into finer vessels. All cells of the body are within a short distance of very fine blood vessels called capillaries. Oxygen diffuses out of the capillaries and into the fluid surrounding cells — the **interstitial fluid**. From there it diffuses into cells where it is used for **respiration**.

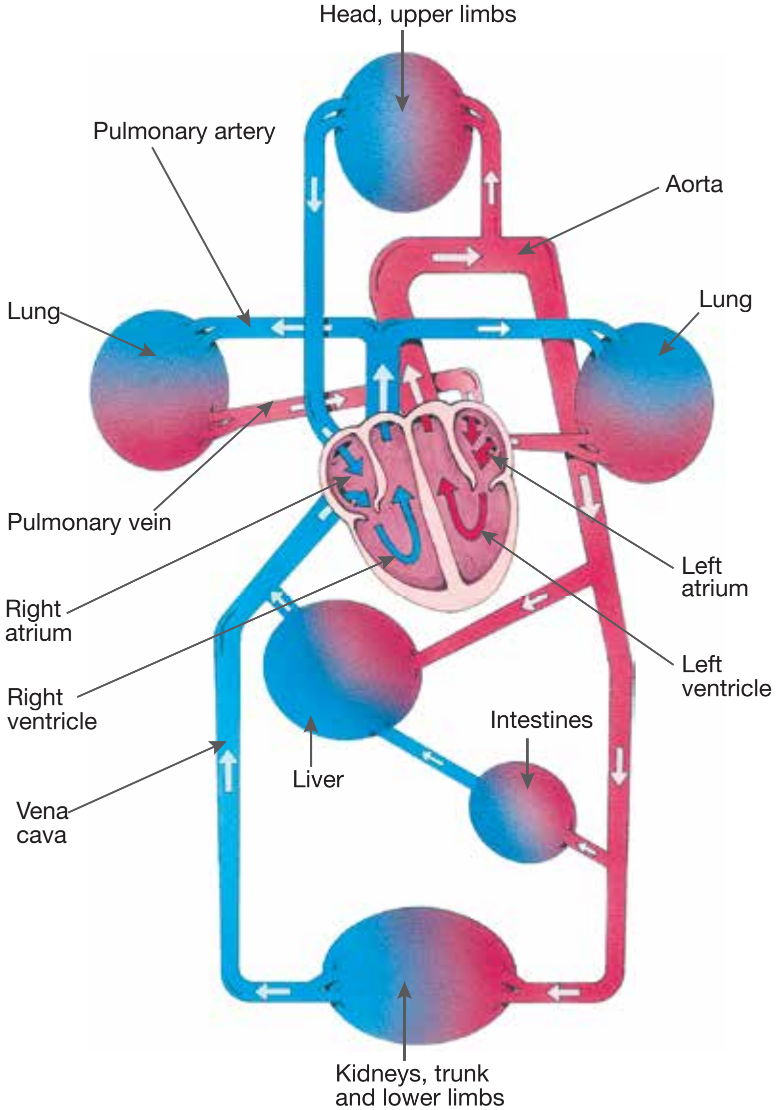
Respiration is a process that releases the energy stored in glucose and converts it to a useable form. In respiration glucose and oxygen react to release carbon dioxide, water and energy. It's a multi-step process but it can be summarised by the following word and symbol equations:

$$\text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

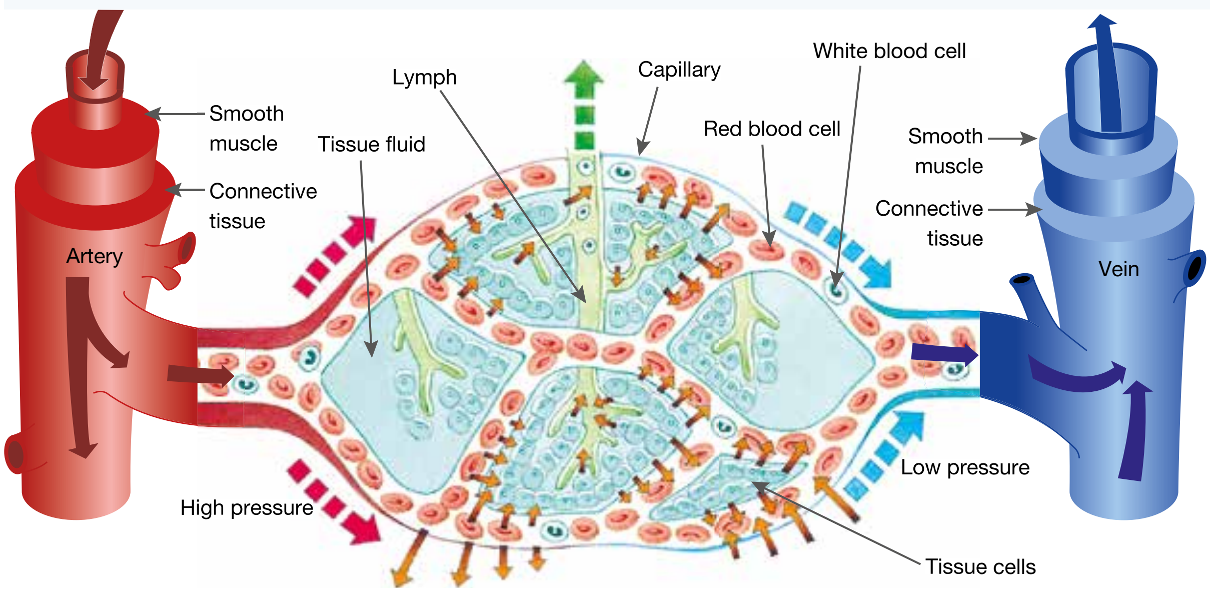
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

The carbon dioxide produced in respiration must be removed from cells. It diffuses out of cells and into the interstitial fluid, then moves into capillaries where it is carried in the bloodstream back to veins and then the heart. The heart pumps blood to the lungs where the carbon dioxide diffuses out of the bloodstream and into the alveoli of the lungs. It is then breathed out.

The circulatory system transports substances around the body.



Oxygen diffuses into the blood in the lungs and is delivered to cells by the circulatory system.



INVESTIGATION 1.2

Model of the respiratory and circulatory system

AIM: To model the role of the respiratory and circulatory systems

You will need:

A4 sheets of white, blue and red cardboard
thick marker

- Use the sheets of white cardboard and the markers to make some signs with the words: lungs, head, right atrium, right ventricle, left atrium, left ventricle, liver, intestines, kidneys, trunk and lower limbs. Use the figure at the top of the previous page to decide how to organise the cards.
- Cut up at least 5 sheets of the red and blue cardboard into 4 smaller cards. Write 'oxygen' on the red cards and 'carbon dioxide' on the blue cards. Give the red cards to student A who will play the role of the lungs. The blue cards should go student B who will play the part of the body cells.
- All the other students in the class will play the part of red blood cells, moving around the circulatory system. Use the figure at the top of the previous page to decide how the red blood cells should move around the room to model the circulatory system.

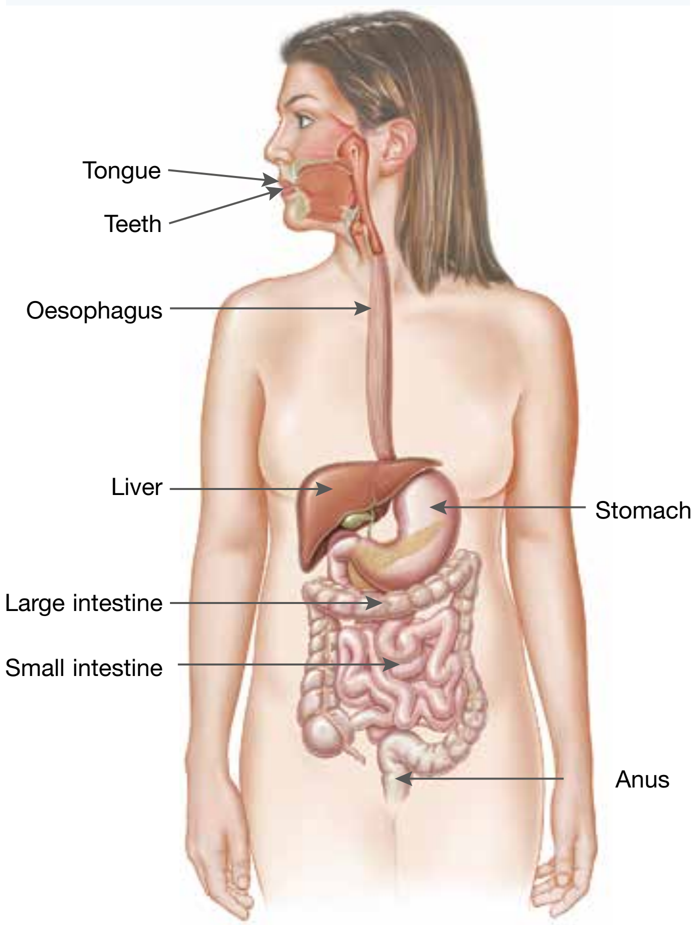
Discussion

1. What are the benefits of using a model such as this one?
2. Identify some limitations of this model. How could it be improved?

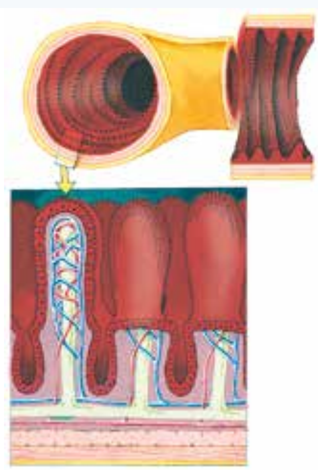
1.2.3 Supplying cells with nutrients

In addition to oxygen, cells also need glucose for respiration, as well as other nutrients such as amino acids, fatty acids, vitamins and minerals that come from the food we eat. The digestive system breaks down food both physically and chemically. By the time it reaches the small intestine many of the carbohydrates in food have been converted to glucose, proteins are converted to amino acids, and fats are broken down into fatty acids and glycerol. These substances pass through the walls of the small intestine and diffuse into the blood in the capillaries of the villi of the small intestine. From there they will be carried in the bloodstream to all cells of the body.

The digestive system



Small finger-like projections called villi line the walls of the small intestine.



1.2.4 Getting rid of waste

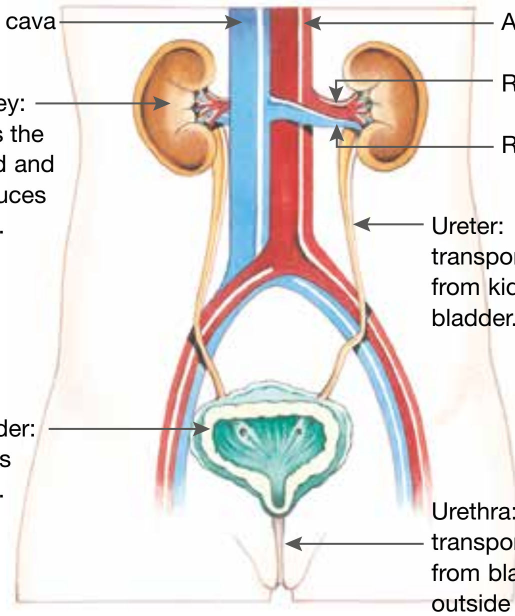
Waste products must be removed from cells to ensure that they do not reach dangerous levels and interfere with normal cell functions.

Carbon dioxide is a waste product of respiration. It is excreted in the lungs.

There is also another type of waste called nitrogenous waste that needs to be removed from cells. It results from protein metabolism. The liver is involved. It processes the nitrogenous waste and converts it to a substance called urea. Urea is transported in the bloodstream. When it reaches the kidneys it is filtered out of the blood. The kidneys produce urine, a solution of urea and other substances including salts. In addition to excreting urea the kidneys are also involved in salt and water balance.

The skin also plays a part in excretion. Excess water and salts and small amounts of urea and uric acid are removed from the body via the skin.

The excretory system



HOW ABOUT THAT!

The human kidneys remove excess salt from the blood to help keep levels constant. Different types of animals have other ways of removing excess salt from their bodies. Turtles, for example, have salt-secreting glands behind their eyes. Hence you may see a turtle 'shedding tears'. On the other hand, penguins and some other seabirds, such as the southern giant petrel, may appear to have runny noses because that is where their salt-secreting glands are located.

1.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Copy and complete the following statements using these words: multicellular; organ; stomach; tissues.
   (a) ______________ organisms are made up of many cells.
   (b) ______________ are made up of similar cells that carry out a particular function.
   (c) An ______________ consists of different types of tissues.
   (d) The ______________ is an organ of the digestive system.
2. Why do cells need oxygen?
3. **Identify** the part of the lungs where oxygen diffuses into the bloodstream.
4. Which molecule does oxygen bind to in the bloodstream?
5. What are carbohydrates, proteins and amino acids converted to in the digestive system?

6. **Identify** the part of the body where nutrients diffuse into the bloodstream.
7. List some substances that must be removed from cells.
8. **Outline** the function of the liver and kidneys in the excretion of nitrogenous waste.
9. **Identify** some substances that are excreted via the skin.
10. Copy and complete the table at right.

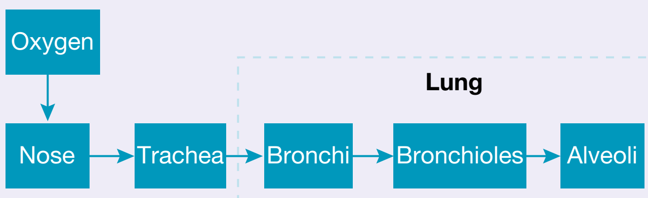
Organ	Function
Kidney	
Bladder	
Ureter	
Urethra	

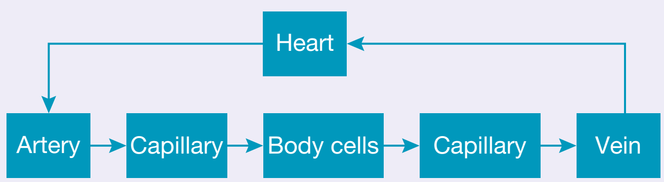
Think

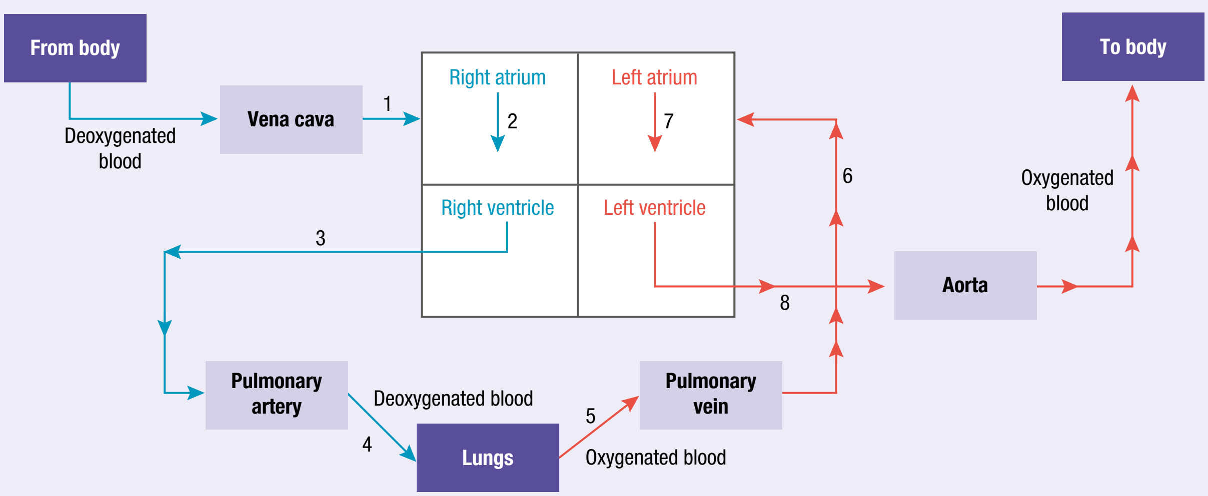
11. **Distinguish** between the terms ‘breathing’ and ‘respiration’.
12. CPR (cardiopulmonary resuscitation) involves chest compressions and artificial respiration (sometimes in the form of mouth-to-mouth resuscitation). **Explain** why:
    (a) It would be pointless to do mouth-to-mouth breathing without chest compressions if a person’s heart had stopped beating.
    (b) CPR needs to be started as soon as possible after a person goes into cardiac arrest (heart stops beating).

Skill builder

13. Study the 3 flow charts below and answer the questions that follow.
    (a) Which process is represented in flow chart 1?
    (b) Draw a diagram similar to flow chart 1 to show the parts of the respiratory system that carbon dioxide would pass through as it is breathed out.
    (c) Flow charts 2 and 3 show the movement of blood around the body. **Compare** the two flow charts by answering the following questions:
        (i) What additional information is shown in flow chart 3?
        (ii) **Identify** an advantage of flow chart 2.
        (iii) In flow chart 3 some of the arrows are blue and some are red. What is this meant to represent?
    (d) Draw a flow chart to show what happens to excess amino acids in the body.







1.3 Keeping things balanced

1.3.1 Homeostatis

Enzymes, the proteins that regulate chemical reactions in the body, work best within a narrow range of conditions. For this reason it is important that blood sugar levels, body temperature, pH and salt levels in the blood are carefully controlled. Conditions inside the human body remain fairly constant despite changes in the external environment. This is known as homeostasis. In most instances it involves a negative feedback mechanism.

1.3.2 Negative feedback

Negative feedback involves the following three steps:

1. A change in the body is detected (e.g. a change in temperature or glucose level).
2. A message is sent to a gland or organ. (*Note:* In some cases this may be a multi-step process.)
3. A response is initiated. The response returns the body to its normal state.

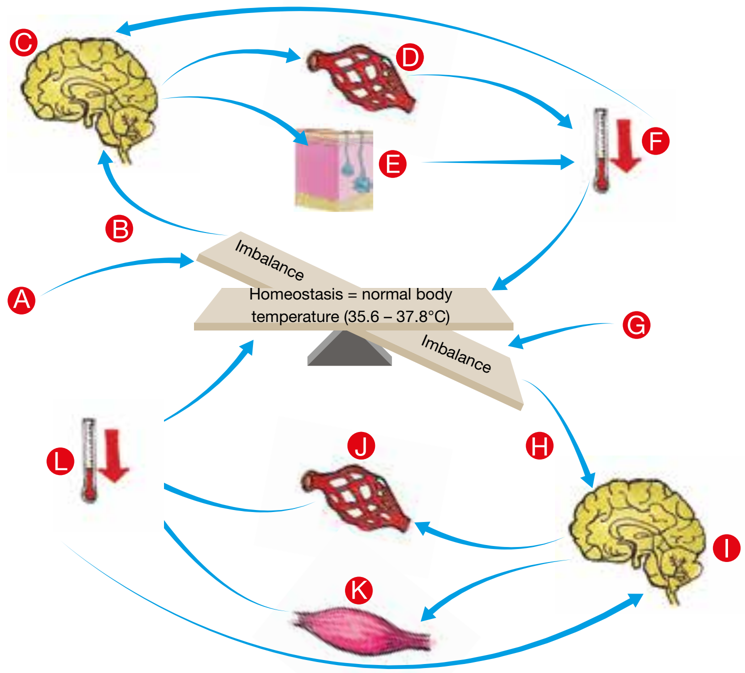
The diagram at right shows how negative feedback is involved in the maintenance of constant body temperature.

Negative feedback is also involved in the maintenance of blood sugar level. The hormone insulin is released by the pancreas when an increase in blood sugar levels is detected. Insulin causes cells, including those of muscles and the liver, to take up glucose, thereby returning blood sugar levels to normal. When blood sugar levels are lower than normal the hormone glucagon, which has the opposite effect to insulin, is released.

1.3.3 It's not all negative

Homeostasis usually involves negative feedback but there are instances of positive feedback in the body as well. Positive feedback is when a change from the normal state triggers a reaction that results in the change being amplified. Contractions becoming gradually more intense during labour

A negative feedback mechanism is involved in the maintenance of constant body temperature.



A Air temperature increases.
B Heat receptors detect increase in temperature and send message to the hypothalamus in the brain. Message travels along nerve cells.
C Hypothalamus sends messages to sweat glands and walls of capillaries close to the skin.
D Capillaries close to the skin dilate and heat radiates from the skin surface.
E Sweat production increases. Heat is lost as sweat evaporates from the skin.
F Temperature returns to normal. Messages from hypothalamus cease and cooling responses are turned off.
G Air temperature decreases.
H Heat receptors detect decrease in temperature and send message to the hypothalamus in the brain. Message travels along nerve cells.
I Hypothalamus sends messages to muscles and walls of capillaries close to the skin.
J Capillaries close to skin contract. Less heat radiates from skin.
K Muscles shiver, generating heat.
L Temperature returns to normal. Messages from hypothalamus cease and warming responses are turned off.

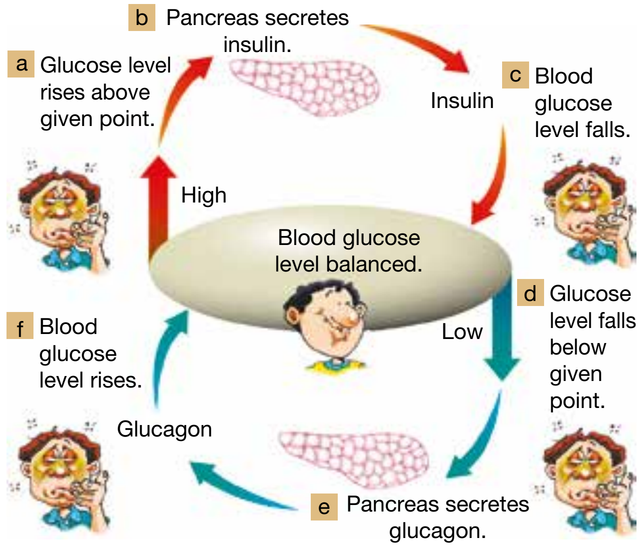
is an example of positive feedback. In the early stages of labour the baby moves into the cervix, the lower part of the uterus that connects to the vagina. This causes stretch receptors in the cervix to fire and bring about the release of a hormone called oxytocin. Oxytocin causes the uterus to contract, pushing the baby further into the cervix and activating the stretch receptors. More oxytocin is released, intensifying the contractions. With continued positive feedback the contractions continue to become stronger until the baby is born. Once the baby is out of the womb the stretch receptors no longer fire. Oxytocin levels fall and eventually the contractions stop.

1.3.4 Salt and water balance

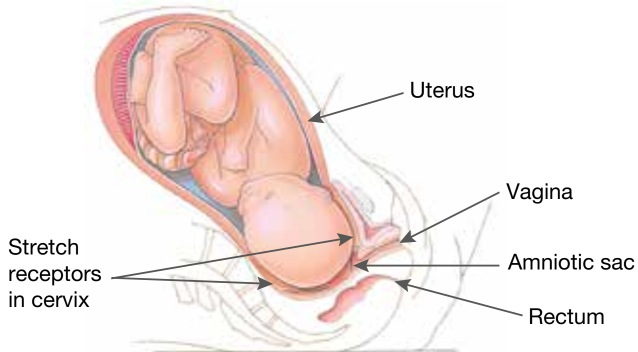
The kidneys do more than just filter blood to remove nitrogenous waste. They also regulate salt and water balance. The process involves negative feedback. Inside the kidneys are structures called nephrons. The part of the nephron called the renal corpuscle is where filtration occurs. The renal corpuscle consists of a network of capillaries called the glomerulus and a structure called the Bowman's capsule. Fluid and small particles pass from the glomerulus into the Bowman's capsule and into a tube called the nephron tubule. Large particles including blood cells remain in the blood. The liquid in the tubule will eventually be excreted as urine, but as it passes through the tubule the composition of the fluid is adjusted. Useful substances are reabsorbed into the bloodstream. Some water is also reabsorbed and salt levels are adjusted. The amount of water and salts that are eventually expelled from the body is carefully controlled. On a hot day or following exercise less water will be excreted than on a cool day.

The hormone ADH (anti-diuretic hormone) is one of the hormones involved in regulating the amount of water excreted by the kidneys. If you drink a lot of water, receptors send a message to the hypothalamus in the brain to release less ADH. Anti-diuretic hormone affects the nephrons in the kidney so that less water is reabsorbed by the nephron. The kidneys produce a large amount of dilute urine. This returns water balance to normal. If you are dehydrated the opposite happens. More ADH is released by the hypothalamus and the kidneys excrete less water to restore water balance. Aldosterone is another hormone involved in salt and water balance.

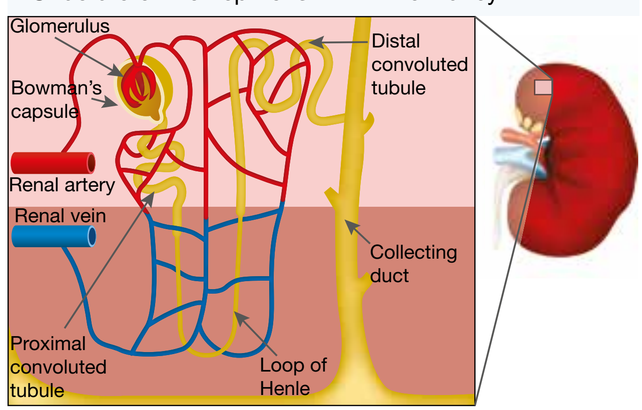
The hormones insulin and glucagon are secreted by the pancreas to control glucose levels in your blood.



As the baby moves into the cervix, stretch receptors fire and stimulate the release of oxytocin, a hormone that triggers contractions of the uterus.



Structure of the nephrons within the kidney



INVESTIGATION 1.3

Kidney dissection

AIM: To investigate the structure of a kidney

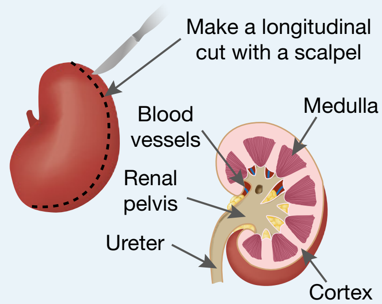
You will need:

kidney (from butcher)
scalpel
newspaper or dissection board
disposable gloves and goggles

CAUTION: To minimise the risk of infection from pathogenic organisms that may be growing on the kidneys, ensure that the kidneys are fresh and refrigerated prior to the dissection. Wear gloves and goggles to carry out the dissection and take care with the scalpel.

- Place the kidney on the dissection tray or newspaper and use a digital camera or mobile phone camera to photograph it. Try to identify the renal artery, renal vein and ureter and label these on your photo.
- Slice longitudinally through the kidney (see diagram). Take a photo and add the following labels to your photo: cortex, medulla, renal pelvis, ureter.

Make a longitudinal incision when dissecting the kidney.



Discussion

1. Compare the colour of the medulla, cortex and renal pelvis.
2. Copy and complete the following sentence: Urine is formed in the ________________ and collects in the _____________. From there it is taken out of the kidney via the ________________.
3. The use of animal organs and whole animals in Science raises ethical issues.
   (a) Explain what is meant by 'ethical issues'.
   (b) What are some factors that might be taken into consideration in deciding whether the use of animals or their organs is justified for a particular scientific investigation?

1.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the following terms: homeostasis, negative feedback, positive feedback.
2. In hot weather **outline** what happens to:
   (a) the capillaries near the skin.
   (b) the sweat glands.
3. **Identify** the hormone that is released when:
   (a) an increase in blood sugar levels is detected.
   (b) a decrease in blood sugar is detected.
   (c) labour begins.
   (d) you are dehydrated.
4. In the table below, match each organ or structure with its function.

Organ	Function
(i) Kidney	(a) Tube leading from kidney to bladder
(ii) Glomerulus	(b) Functional units of the kidney
(iii) Nephrons	(c) As urine travels along this tube its composition is adjusted.
(iv) Tubule	(d) Organ that filters blood
(v) Ureter	(e) Network of capillaries in renal corpuscle

Think

5. What happens to the hairs on your arms and legs in cold weather? Suggest why.
6. Suggest why your face might become flushed in hot weather and your lips might appear blue in cold weather.
7. There are many more examples of negative rather than positive feedback in the human body. Suggest why.
8. Use the **Negative feedback** weblink in the Resources tab to see how a thermostat is used to model how negative feedback works.
   (i) What is the advantage of using a model in this instance?
   (ii) In what way is a thermostat different to the way in which the human body regulates body temperature?
9. In type 1 diabetes the pancreas does not produce sufficient insulin. Insulin must be administered regularly either by injection or with the use of an insulin pump. **Explain** why a person who has type 1 diabetes needs to monitor the amount of carbohydrate they eat and adjust the amount of insulin they take in accordingly.

Skill builder

10. Study the table at right.
    (a) Present the information in the table at right in the form of a column graph.
    (b) Proteins are large molecules. Suggest why the concentration of protein in urine is 0%.
    (c) Glucose is a small molecule. What must happen to glucose in the nephron tubule?
    (d) Would you expect the amount of water, salt and urea in urine to remain constant from one day to the next? **Explain** your answer.

A comparison of what is found in blood and in urine

	Quantity (%)	
Substance	**In blood**	**In urine**
Water	92	95
Proteins	7	0
Glucose	0.1	0
Chloride (salt)	0.37	0.6
Urea	0.03	2

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Complete this digital doc: Worksheet 1.1: The endocrine system (doc-12735)

1.4 Detecting change

1.4.1 Types of receptor cells

The first step in homeostasis is to detect a change from the normal state. Once the change has been detected it can be corrected. Receptor cells are a special type of nerve cell that identify changes in the environment both inside and outside the body. In humans many receptor cells are located in the sense organs including the eyes, ears, skin, nose and tongue.

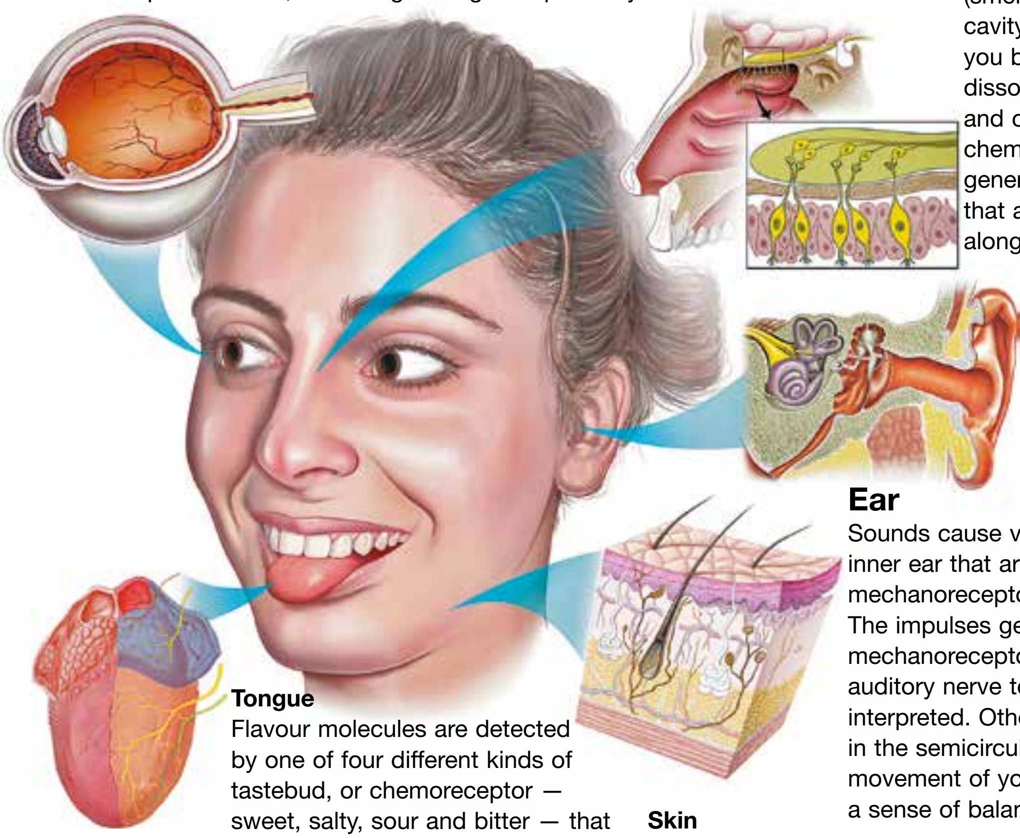
Type of receptor	Stimulus these receptors respond to	Example of places where these are found
Chemoreceptors	Chemicals	Tongue
Photoreceptors	Light	Eye
Mechanoreceptors	Pressure or distortion	Skin, inner ear
Thermoreceptors	Heat	Skin

There are different types of receptor cells. Each type responds to a particular stimulus. Once receptor cells detect a stimulus, a message in the form of a nerve impulse is sent from the receptor cell. A nerve impulse is a message that travels along nerve cells as a progressive wave of electrical and chemical activity. The message eventually reaches the central nervous system (the spine and brain).

What role do the sense organs play in keeping you alive?

Eye
Photoreceptors in the retina of the eye detect light. There are two types of photoreceptor: rods and cones. Rods cannot detect colour, but only low light is needed to trigger a nerve impulse from rod cells. Cones are involved in colour vision. In humans cone cells respond to blue, red and green light respectively.

Nose
Molecules of gas, including those that cause odour (smell), enter the nasal cavity of your nose when you breathe in. There they dissolve in the mucus and cause the cilia of the chemoreceptor neurons to generate nerve impulses that are sent to the brain along the olfactory nerve.



Ear
Sounds cause vibrations in the inner ear that are detected by mechanoreceptors in the cochlea. The impulses generated by the mechanoreceptors travel along the auditory nerve to the brain to be interpreted. Other mechanoreceptors in the semicircular canals detect movement of your head and give you a sense of balance.

Tongue
Flavour molecules are detected by one of four different kinds of tastebud, or chemoreceptor — sweet, salty, sour and bitter — that are located on the tongue surface. Each tastebud contains one of the four types of chemoreceptor.

Skin
The skin contains mechanoreceptors that detect vibration, pressure, touch and pain. Touch and pressure receptors are stimulated by compression of the skin. Thermoreceptors in the skin detect heat.

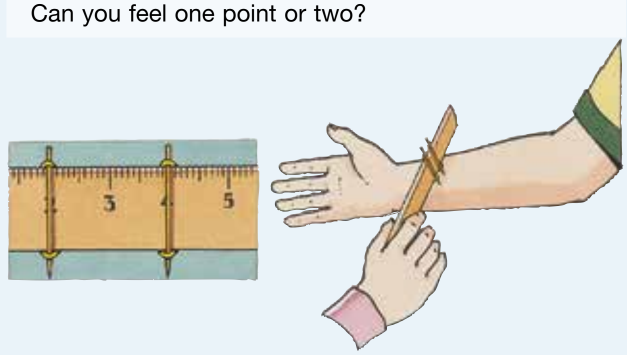
INVESTIGATION 1.4

Touch receptors in the skin

AIM: To detect where skin is most sensitive to light contact

You will need:
2 toothpicks
ruler
2 rubber bands
blindfold

Can you feel one point or two?



- Draw a table like the one on the right in your workbook.
- Use rubber bands to attach twvo toothpicks to a ruler so that they are 2 cm apart.
- Blindfold your partner. Gently touch your partner's inside forearm with the points of the two toothpicks.
- Ask your partner whether two points were felt. Move one toothpick towards the other in small steps until your partner is unable to feel both points. To make sure that there is no guesswork, use just one point from time to time.
- Record the distance between the toothpicks when your partner can feel only one point when there are really two points in contact.
- Repeat this procedure on the palm of one hand, a calf (back of lower leg), a finger and the back of the neck.
- Swap roles with your partner and repeat the experiment.

Where is your skin most sensitive?

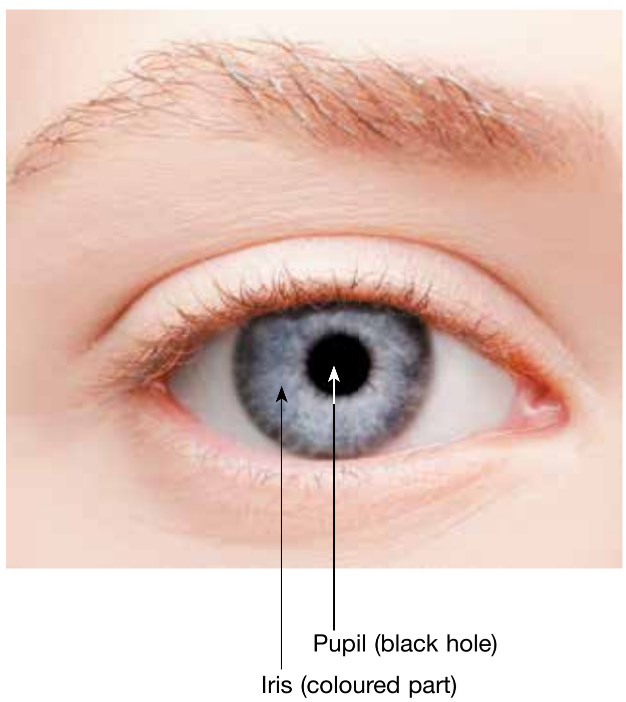
	Distance (cm) between two points when only one point is felt	
Part of the skin	**Your partner**	**You**
Inside forearm		
Palm of hand		
Calf		
Finger		
Back of neck		

Discussion

1. Which area of the skin was most sensitive?
2. Which area of the skin was least sensitive?
3. Suggest why the skin is not equally sensitive all over the body.
4. Which parts of the skin are likely to have the most touch receptors that respond to light contact?

1.4.2 The eye — a complex organ

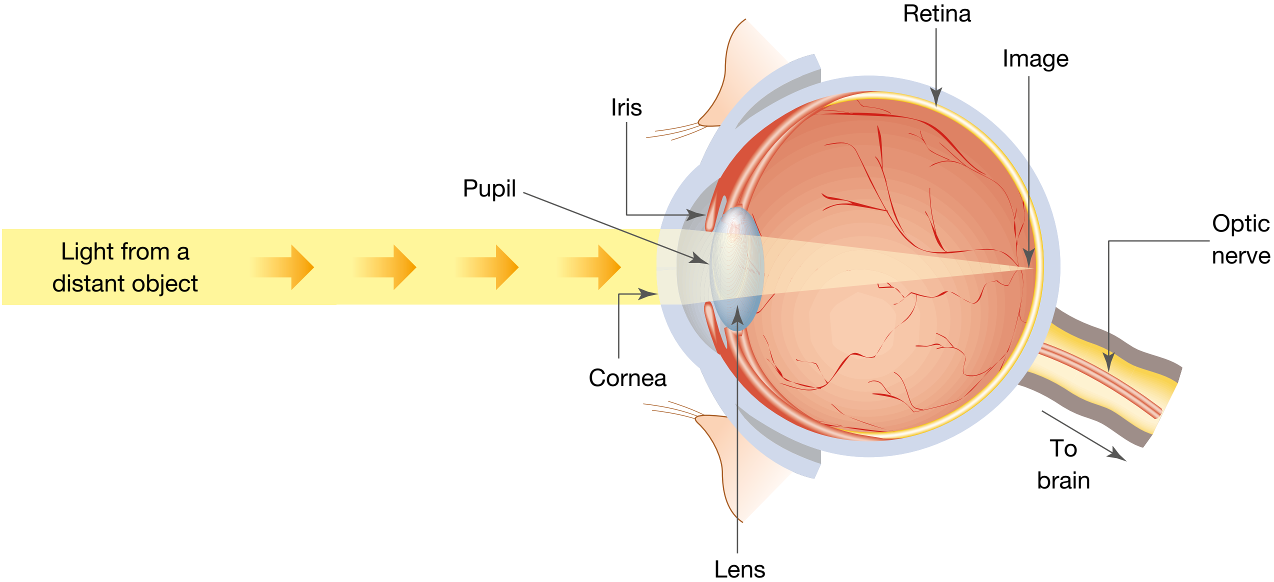
Your eyes, like your other sense organs, are made up of many different parts, each with its own special job to do. Look into a mirror (or into the eyes of the person next to you). The dark spot in the centre of your eye is called the **pupil**. Your pupil is simply a hole in the **iris**. Your iris is the coloured part of your eye. The amount of light entering into your eye is determined by the size of your pupil, which is controlled by your iris. Your iris is a ring of muscle, so when it relaxes the pupil appears bigger, letting more light into the eye; and when it contracts, the pupil looks smaller, letting less light into the eye.



1.4.3 Getting the picture

The **cornea** is the clear outer layer of your eye. It is curved so that the light approaching your eye is bent towards the pupil. The clear, jelly-like **lens** bends or focuses light onto a thin sheet of tissue that lines the inside of the back of your eye called the **retina**. The lens is connected to muscles which can make it thick or thin. This allows your retina to receive a sharp image of distant or nearby objects. **Short-sightedness** and **long-sightedness** are conditions in which a sharp image is not received on the retina. In these cases, the image can be sharpened by using artificial lenses such as those in spectacles.

A number of structures within your eye function together so you can detect and respond to light.



Although your eye receives light and produces an image of what you see, it is your brain that interprets and makes sense of the image. The photoreceptors in the retina respond to the light stimuli by sending signals to your **optic nerve** which then forwards them to your brain for interpretation.

INVESTIGATION 1.5

Getting an eyeball full!

AIM: To investigate the structure of an eye

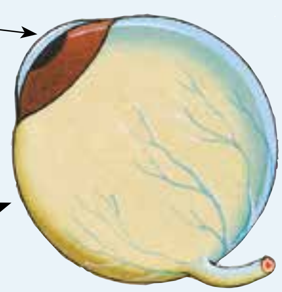
You will need:

bull's eye or similar
safety glasses
dissection board
forceps
newspaper
stereo microscope
paper towelling
water
scalpel or razor blade

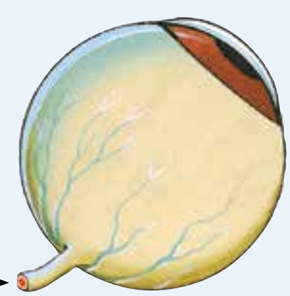
CAUTION: In this activity you will be using sharp instruments. Discuss with your teacher and other members of the class a list of safety rules that should be followed carefully before beginning this activity.

- Carefully place the bull's eye on a dissection board which has been covered with newspaper and paper towelling.
- Draw and label the structures of the bull's eye before and after your dissection. (Use the diagrams below and on the next page to help you to label your drawing.)

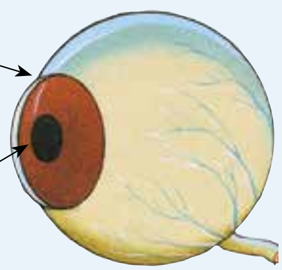
1. Place bull's eye on dissection board covered with newspaper. Locate the transparent skin of the cornea.



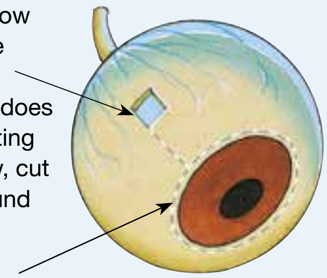
2. Locate the optic nerve. It is a hard, white solid tube at the back of the eye. You may have to remove some fat to see it.



3. Look at the coloured part of the eye (iris) and the black part in the centre (pupil).



4. Cut a small window in the eyeball. Be careful that the vitreous humour does not run out. Starting from this window, cut forward and around the iris.



- Add descriptive comments to your labels as you make your observations throughout this activity.
- Put on safety glasses just in case any of the aqueous or vitreous humour squirts out at you. Aqueous and vitreous humour are jelly-like liquids which give eyes their shape.
- Carefully cut a small window just behind the iris using a razor blade or scalpel. Record your observations regarding the toughness of the sclerotic coating.
- From this window, cut towards and then all the way around the iris so that you have cut the eye into two parts.
- Lift off the top part of the eye and examine the iris.
- Remove the lens with forceps and see if you can read the print on the newspaper through it.
- Use water to rinse out the jelly-like material (humour) from inside the eye and examine the retina.
- Follow your teacher's instructions regarding the cleaning of your equipment and disposal of the dissected eye.

Discuss and explain

1. What is the black part in the middle of the iris?
2. What did you observe when you looked at the newspaper through the lens?
3. What did the retina look like? Could you find the optic nerve?
4. Summarise your findings in a table underneath your labelled bull's eye drawings.
5. What does the diaphragm in a microscope do? Which part of the eye does the diaphragm in a monocular microscope most resemble?
6. Find out more about one of the parts of the eye that you have observed, such as its function, related diseases or surgery.

1.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What name is given to all of the neurons that detect change in your sense organs?
2. **Outline** what a receptor does when it detects a change.
3. **Identify** the two types of photoreceptor cells in the eye.
4. Complete the below table.

Sense organ	Stimulus	Type of sensory neuron
Eye	Light	Photoreceptor
	Sound and gravity	
Nose		
	Chemical flavours	
	Vibration, pressure, touch and pain	

5. **Identify** the function of each of the following parts of the eye:
   (a) lens
   (b) iris
   (c) optic nerve.
6. Jayden has good close vision but distant objects appear blurry to him. Is he short-sighted or long-sighted?

Think

7. **Identify** the sense organs and sensory neurons that would be involved in detecting:
   (a) a bee flying towards you?
   (b) a tennis ball hitting you?
   (c) hot chocolate entering your mouth?
8. If the human eye contains only 3 types of cone cells (red, blue and green) **explain** why are we able to see a huge variety of colours.
9. Have you noticed that food tastes really bland when you have a blocked nose? Use the information about the nose and the tongue in this subtopic to suggest why.
10. **Deduce** why the thickest part of your skin is on the soles of your feet.
11. **Explain** why some parts of your skin, such as the back of your hand, are more sensitive to heat than others.

Research

12. Use the **Eyeball 1 and 2** weblinks in the Resources tab to learn more about the name and function of the parts of the eye.

Investigate

13. With a partner, play a guessing game to see how well you can use your sense of touch alone to **identify** 10 unknown objects.
14. You will need a blindfold and 10 objects of about the same size. Sandpaper, plastic, coins and pieces of carpet, polystyrene, nylon and wool would be ideal. See who can **identify** the most objects correctly.

learnon Resources — ONLINE ONLY

Explore more with this weblink: Eyeball 1

Explore more with this weblink: Eyeball 2

1.5 Fast control!

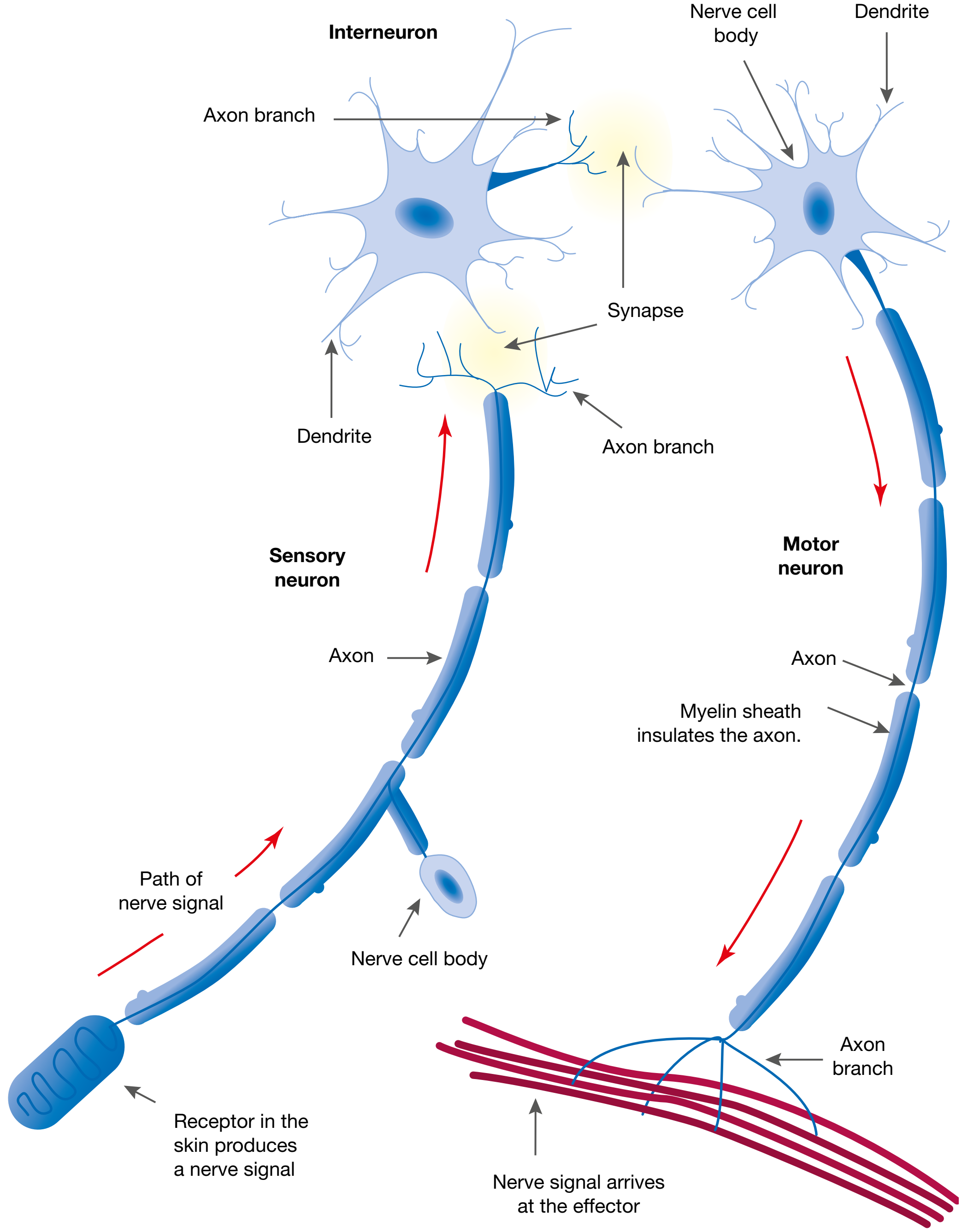
1.5.1 The nervous system

Your nervous system has an important role in the coordination and control of your body. Messages from receptor cells are transmitted along nerves to the central nervous system where they are processed and a response is initiated. Messages then pass along nerves to muscles or glands to bring about a response.

The nervous system is composed of the **central nervous system** (the brain and spinal cord) and the **peripheral nervous system** (the nerves that connect the central nervous system to the rest of the body). Once receptor cells have detected a **stimulus**, information about the stimulus in the form of electrical impulses (nerve signals) passes rapidly from the receptors and along the peripheral nervous system to the central nervous system. These electrical impulses travel through the nervous system via **neurons** (also known as nerve cells). Neurons grouped together form a **nerve**.

There are three different types of neurons: **sensory neurons**, which carry the impulse generated by the stimulus to the central nervous system; **interneurons**, which then carry the impulse through the central nervous system; and **motor neurons**, which take the impulse to **effectors** such as muscles or glands. The response from these effectors depends on the original stimulus. For example, if you put your hand on the hotplate of a stove, the response is for your arm muscles to move your hand away from the hotplate.

Relationship between the sensory neuron, interneuron and motor neuron



1.5.2 The structure of a neuron

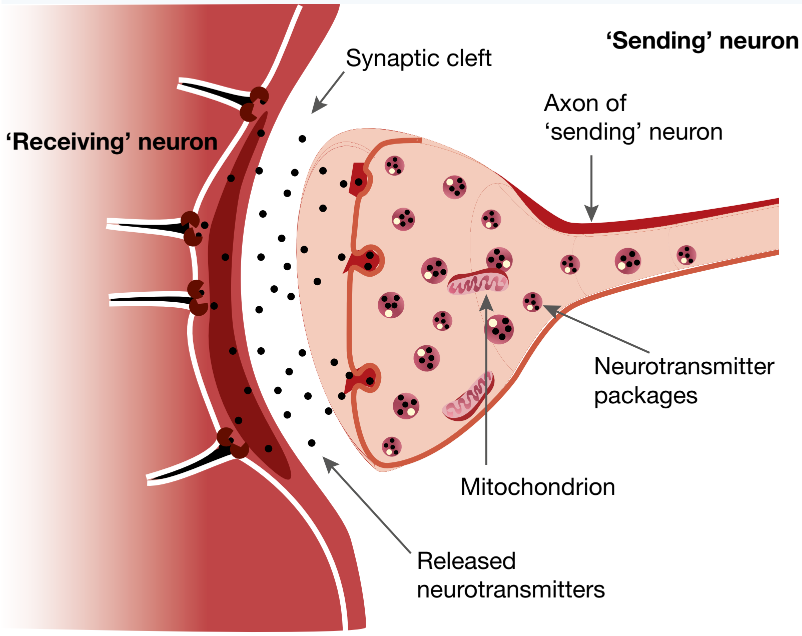
A neuron is a long cell with the following features:

- a **cell body** containing a nucleus. It supplies energy and nutrients for the activity of the neuron.
- **dendrites**, fine branches that extend from one end of the cell and receive messages from receptors and other neurons
- an **axon**, which is a long structure through which the nerve impulse passes along. There are axon branches at the end of the axon. The axon is electrically insulated by a sheath or covering made of myelin. Nerve impulses travel along a neuron in one direction only — from dendrite to axon branch.

1.5.3 Passing the message on

Nerve impulses need to be passed on from one neuron to another. This happens at the synapse, the junction between two nerve cells. There are also synapses where neurons connect to effector organs. When an impulse reaches the **axon terminals** of a neuron, it causes chemical compounds called **neurotransmitters** to be released into the synaptic cleft, the gap between the axon terminal and the cell that the message needs to be passed along to. The neurotransmitter locks onto receptors in the membrane of the cell on the other side of the synapse and this causes the cell to 'fire'. Thus, each impulse is passed on from one neuron to the next until it eventually ends at a muscle or gland, which, in turn, responds. While the impulse travels, it changes from an electrical message (within the neuron) to a chemical message across synapses, then back to an electrical message again in the next neuron.

A synapse



Many substances including alcohol, some painkillers, drugs such as heroin and cannabis, and some medicines prescribed to treat depression affect the way in which messages pass from one nerve cell to another.

HOW ABOUT THAT!

Ever noticed that you are often in a better mood after doing some exercise? When you exercise your brain releases neurotransmitter molecules called endorphins. Endorphins are morphine-like chemicals that act as natural painkillers. They block out some of the mild pain associated with exercise. It is not known whether the endorphins themselves result in an improved mood or whether the endorphins interact with the release of other brain neurotransmitters. Exercise is such a powerful mood enhancer that in cases of mild depression doctors will sometimes prescribe a daily walk or some other form of exercise.

1.5.4 Watch out!

Have you ever had sand thrown in your eyes or touched something too hot? Sometimes you don't have time to think about how you will react to a situation. Some actions need to be carried out very quickly. These reactions may require only a few neurons.

The pathway shown at right is known as a **reflex arc**. No conscious thought is required for this type of action. The impulse follows a direct route from the receptor to the effector with an interconnecting link in the spinal cord. Additional impulses are sent to the appropriate part of the brain to keep it 'informed' of what happened. The reflex arc can be described in terms of a stimulus — response model. The stimulus may be the heat from a flame and our response may be to move away from the flame quickly.

This response involves a reflex arc.

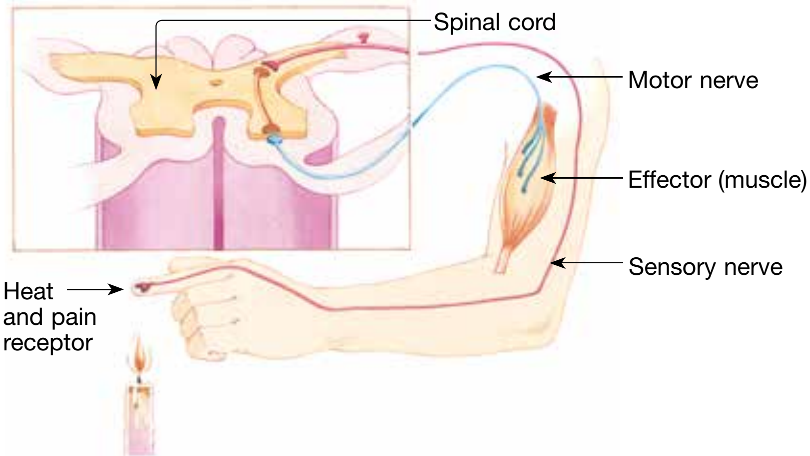
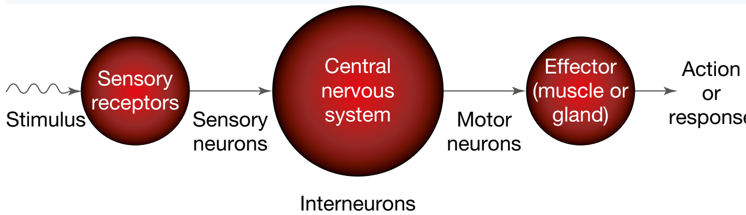


Diagram of the reflex arc



INVESTIGATION 1.6

How good are your reflexes?

AIM: To investigate some automatic responses

You will need:

a well-lit room
stopwatch or clock with a second hand
chair

- Work in pairs for both parts of this activity. Decide who will be the experimenter and who will be the subject. Then swap roles and repeat both parts.

Part A: Kept in the dark

- If you are the experimenter, look closely at the eyes of your partner, noting the size of the pupils.
- Ask your partner to close his or her eyes for 60 seconds.
- At the end of this time, monitor your partner's eyes for any changes.

Your pupil is not always the same size.

Discussion

1. What changes did you notice?
2. What was the stimulus?
3. What was the response?
4. Why do you think this reflex action is important to our survival?
5. Can you control the size of your pupil?

Part B: Knee jerk

Have your partner sit on a chair with one leg crossing over the other knee. Use the edge of your hand to gently strike the crossed leg of your partner just below the knee in the joint. You may need to repeat this a few times to get a response from your partner.

Discussion

6. What happened?
7. What was the stimulus?
8. What was the response?
9. What was the effector?
10. Did you get the response the first time? Why or why not?
11. Can you control a knee-jerk response?

1.5.5 Think about it

More complex actions involve many interconnecting neurons and specialised parts of the brain. The messages pass into and along the spinal cord to be interpreted. When **thinking** takes place, we can make decisions about which responses are needed. Impulses are then sent along appropriate motor neurons to the effectors. This is called a **conscious response**. Many learned actions can become automatic if the same pathways are used often enough. Skill development and control in playing musical instruments and sport, for example, depend on practice during which the same pathways are often used.

1.5.6 Chemical warfare

Beware of toxic ticks, stinging trees, nasty nettles or jellyfish! Many plants and animals have ways of repelling boarders or paralysing their prey.

How do they do it? Blue-ringed octopuses, paralysis ticks, tiger snakes and other animals and plants produce cocktails of poisons that block the production and action of neurotransmitters at synapses. The poison from a red-back spider, for example, empties the impulses out of the neurotransmitters. Interfering with the neurotransmitters' job of carrying the message to the next neuron interferes with the transference of the message and can cause spasms and paralysis.

Many plants produce chemicals that sting by strongly stimulating the pain receptors in the skin. Messages are sent rapidly to the brain, which interprets them as pain. Other plants, including chrysanthemums, produce insecticides such as pyrethrums. These target the nervous system of insects, resulting in their death. The commercial production of such natural pesticides is a large industry and is regarded as environmentally friendly because natural pesticides replace the use of more harmful chemicals.

Some chemicals can specifically target your nervous system and disrupt its functioning. Scientists and experts working with dangerous materials use suits such as the suit shown here for protection.

Similar chemicals have been used as agents of human warfare. These chemicals specifically target the nervous system. Nerve gas, for example, contains a substance which prevents neurotransmitters functioning properly at the synapses. The neurotransmitters accumulate, causing the nervous system to go haywire. Such chaos can result in death.

The first nerve gas, tabun, was initially developed when German scientists were developing a better insecticide. This has led to more deadly agents such as sarin and VX. All nerve gases block the body's production of an enzyme called acetylcholinesterase. This enzyme regulates the nerves controlling the action of particular muscles. A deficiency of acetylcholinesterase leads to tightening of your diaphragm, convulsions and death.

1.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Copy and complete:
   (a) The central nervous system consists of the__________ and the ___________ __________.
   (b) The ______________ nervous system consists of all the nerves that connect to the central nervous system.
   (c) Sensory and effector nerve cells have a long tail-like structure called an ____________.
   (d) The junction between two nerve cells is called a _______________.
   (e) A reaction that does not involve conscious control is called a _____________ action.
2. Copy and complete the table at right.
3. **Explain** why animals need a nervous system.
4. **Describe** the role of neurotransmitter molecules at a synapse.
5. **Distinguish** between:
   (a) a receptor and an effector
   (b) a sensory neuron, an interneuron and a motor neuron
   (c) a neuron and a nerve
   (d) a reflex action and a conscious response.

Type of neuron	Function	Structure
Sensory	Carry nerve impulses from sense organs to central nervous system	
Interneuron		
Motor neuron		Long axon

6. **Construct** a diagram to describe how impulses are transmitted between sensory and motor neurons.
7. **Describe** one way in which animals can cause paralysis.
8. **Describe** how some plants defend themselves against:
   (a) humans
   (b) insects.

Think

9. **Explain** why the axon of neurons is covered with a myelin sheath.
10. Which of the following are reflex actions?
    blinking, clapping your hands, coughing, blowing your nose, sneezing, shivering
11. **Identify** the reflex action that occurs when:
    (a) dust gets caught in your nose
    (b) you step on a prickle.
12. Politicians are sometimes accused of having 'knee-jerk reactions'.
    (a) **Define** the term 'knee-jerk reaction'.
    (b) How do you think the term got its name?
13. Why does the pupil of your eye grow bigger in dim light?
14. How does blocking the production and action of neurotransmitters cause paralysis?
15. Suggest why nerve gas is used in warfare.

Investigate

16. **Investigate** the effects of an illness on the nervous system. Choose one of the following: polio, multiple sclerosis, Alzheimer's disease, Parkinson's disease, mad cow disease.
17. There is a danger that chemical and biological weapons may be used in acts of terrorism.
    (a) Search the media for relevant examples of chemicals and their effects.
    (b) Report on your findings and discuss them with your team.
    (c) Is the use of chemical warfare ever justifiable? **Discuss** this with your team, recording all the various opinions and views.
    (d) What sorts of strategies do we have in Australia to cope with threats of chemical warfare? How effective do you consider these to be? In your teams, brainstorm other strategies that could be used.
    (e) On your own or in a team, write a story, newspaper article or diary entry that describes the effects of a chemical warfare attack in Australia.

learnon RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 1.2: The nervous system (doc-12736)

1.6 Brain power

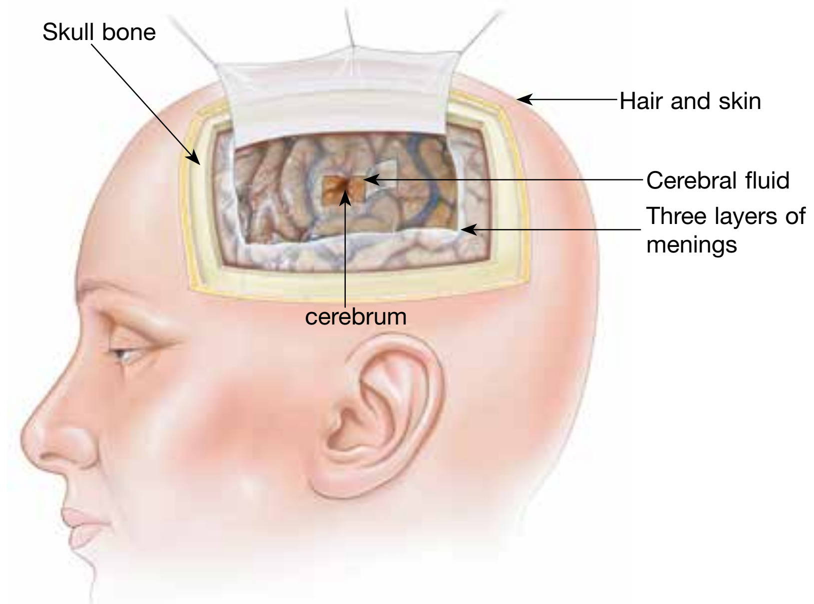
1.6.1 The body's control centre

It weighs about 1.5 kg, sends thousands of messages each second and is more complicated than any computer ever made. What is it? It's the human brain, of course!

Your brain is your control centre. It enables you to learn and store information, and perform complex physical and mental tasks because of your ability to think. It also controls your actions and feelings.

Your brain is well protected within a bony skull. It is also covered with three layers of connective **tissue** called **meninges**, and is surrounded by **cerebral fluid** that cushions it against bumps and knocks.

Structures protecting the brain



HOW ABOUT THAT!

Did you know that your brain:
- is made up of about 80% water, 10% fat, 8% protein and small amounts of other substances?
- is made up of about one hundred billion cells and is the most complex organ in your body?
- will grow to about the size of a large grapefruit?

Like your thumbprint, your brain is unique. Not only is it a different size and weight from your friends, but the learning connections between cells in your brain are different as well. These connections are made as a result of your experiences, and this forms your own personal 'cognitive map'. This difference in our brain's 'internal wiring' can explain why people at the scene of the same accident can have such different eyewitness reports.

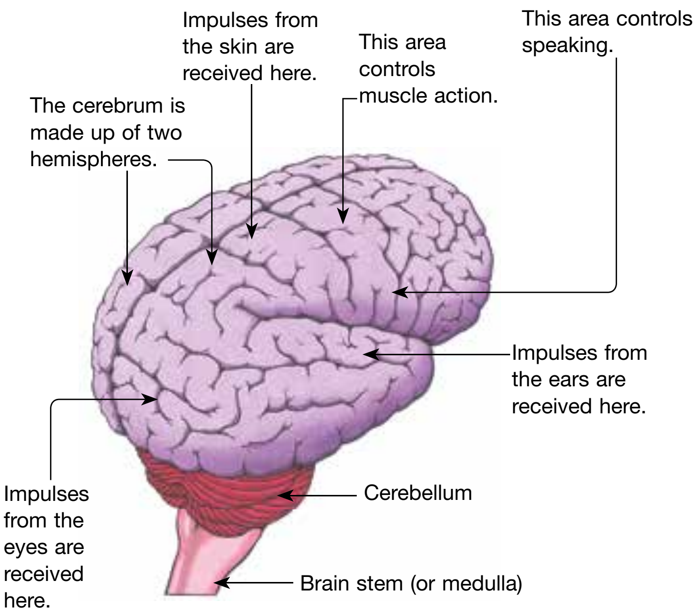
1.6.2 Parts of the brain

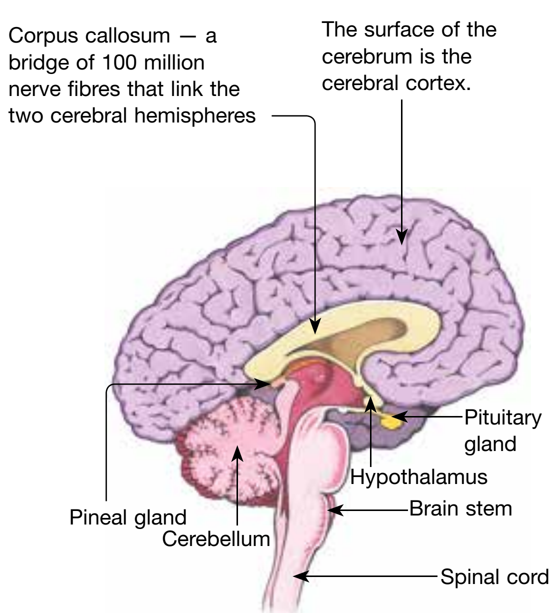
The human brain consists of three main sections: the **cerebrum**, the **cerebellum** and the **brain stem**.

The cerebrum makes up 90% of the brain's volume and is composed of two grey, wrinkly hemispheres. It looks grey because it contains a lot of grey matter (the **cell** bodies of interneurons) and a little white matter (the **myelin sheath** that protects axons). The cerebrum controls memory, speech and thought. All of our **conscious actions**, such as walking, running and speaking, are also controlled by the cerebrum.

The cerebellum sits towards the back of the brain, underneath the cerebrum, where the skull curves inwards. It has a wrinkly surface too, but is pink in colour. The cerebellum controls balance and coordinates complex muscle actions. Footballers can jump and kick, netballers can shoot for goal, rollerbladers can balance and we can all walk without falling over because of the cerebellum's coordination.

The brain stem, sometimes called the medulla, controls the activities in our body that we don't think about. It controls our unconscious or involuntary thoughts, including breathing, heart rate and digestion. The brain stem connects directly to the **spinal cord**. Injury to the brain stem generally results in immediate death.





Scientists have been able to determine the function of the various parts of the brain by observing people with brain injuries and through experiments where electrodes are used to stimulate particular parts of the brain. There have been some interesting cases where damage or a **tumour** in a particular part of the brain has affected a very specific skill, such as remembering names of common objects.

INVESTIGATION 1.7

Brain dissection

AIM: To investigate the structure of a brain

You will need:

a semi-frozen sheep's brain
dissecting board
dissecting instruments (scalpel, forceps, scissors)
plastic ruler
paper towel
gloves

CAUTION: Handle dissecting instruments with care and ensure they are placed in a sterilising solution after use. Wear gloves throughout the dissection and wash your hands thoroughly at the end.

- Place the brain so that the cerebral hemispheres are at the top of the board and the brain stem is at the bottom.
- Identify the external features of the brain: the cerebral hemispheres, cerebellum and brain stem.
- Use your forceps and try to lift the meninges (membranes protecting the brain). You may be able to observe the cerebral fluid between these membranes and the hemispheres.
- Carefully observe the overall appearance of each structure and, using a plastic ruler, measure its size (length, width and height). Include this information in a table.

	Appearance			
Brain structure	**Colour**	**Texture**	**Other features**	**Size**
Cerebrum				
Cerebellum				
Brain stem				

- Draw a diagram of the sheep's brain, labelling the external features.
- On your diagram, identify and label the part of the brain that controls the sheep's:
  (a) heart rate
  (b) balance required for walking
  (c) ability to locate its lamb.
- Using your scalpel, cut the brain in half between the right and left hemispheres, and separate the two cerebral hemispheres.
- Draw a cross-section of the brain. Be sure to label it!
- Now, make a second cut down through the back of one of the hemispheres to see inside the cerebellum and brain stem.

Discussion

1. Which structures contain the grey and white matter?
2. Which part of the sheep's brain is the biggest?

1.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Name the three major structures of the brain and **outline** the main function of each.
2. **Recall** the three structures that protect the brain.
3. **Explain** why the 'grey' matter is concentrated in the cerebrum.
4. **Identify** the part of the brain that controls:
   (a) breathing
   (b) balancing on a skateboard
   (c) puzzle solving
   (d) creative writing.

Think

5. **Explain** why a major injury to the brain stem is often fatal.
6. If meninges are membranes that protect the brain, what is meningitis?
7. The brain of an average elephant weighs about six kilograms. **Explain** why it needs to be so large. (*Hint*: It is not because an elephant never forgets!)

Investigate

8. If the left side of the brain is damaged in an accident, it's often the right side of your body that is affected. **Investigate** why.

1.7 Scientific research — spinal injuries

Science as a human endeavour

1.7.1 Spinal injury

There are many reasons why a person may need to use a wheelchair to get around. Sometimes a spinal injury is the cause, where damage to the spinal cord can result in loss of sensation and mobility. However, the extent of paralysis depends on the severity and location of the injury.

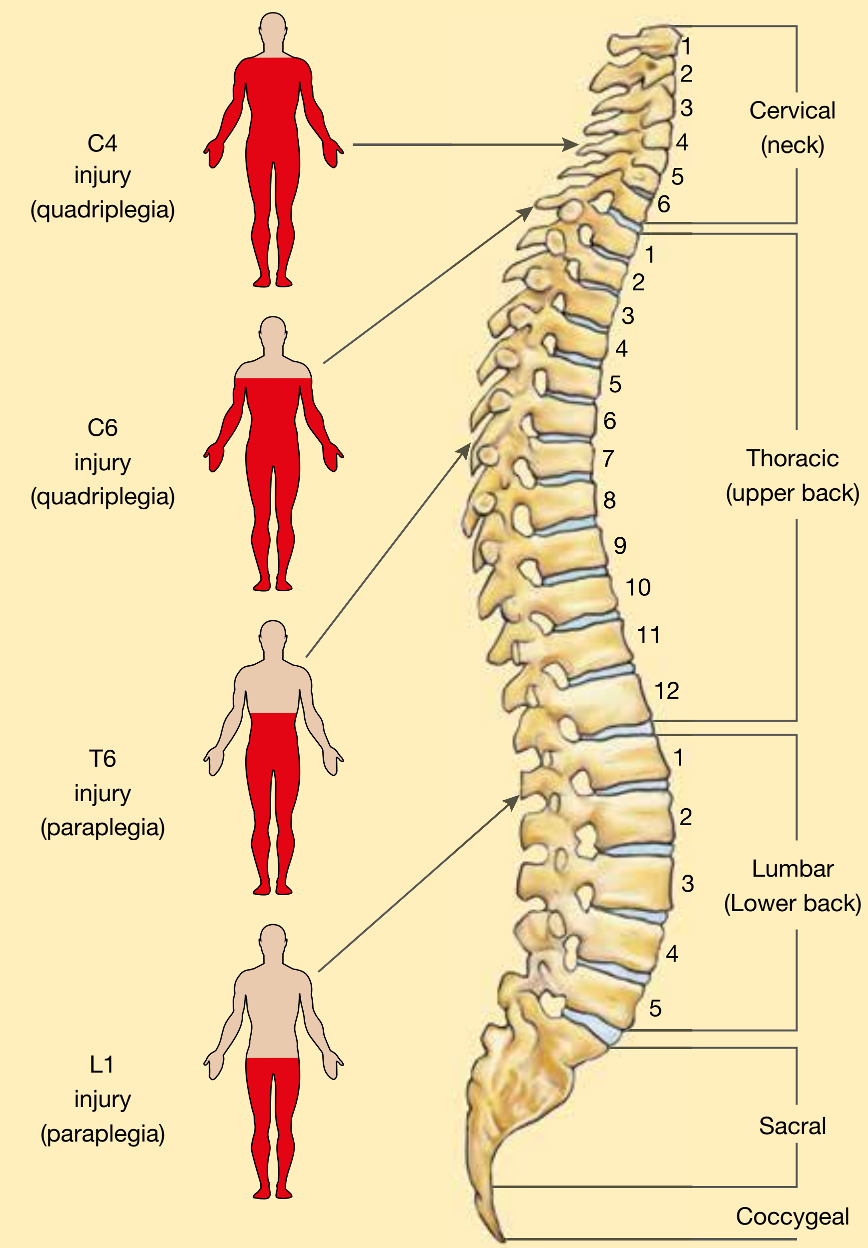
There is currently no cure for spinal injury, but teams of scientists are doing research that may improve the quality of life of people living with spinal injury and possibly take us closer to finding a cure.

All the nerves that run through your body join the spinal cord. Damage to the spinal cord can prevent messages from travelling between your brain and other parts of the body. If your spinal cord was completely crushed in the lower back section of your spine for example, messages would no longer be able to travel from your legs and feet up to your brain and back down again. That means that you would not be able to feel pain, heat, cold or touch in these parts of your body. Also, you would not be able to control the muscles in your legs and feet, so you would not be able to walk.

Damage to your spinal cord in the neck area could result in loss of mobility in your arms, legs and torso. You may not even be able to breathe without a machine blowing air in and out of your lungs. The figure at right shows how the location of

Damage to the upper part of the spinal cord will usually result in greater loss of mobility than damage lower down the spine.

Levels of injury and extent of paralysis



the injury can affect the extent of paralysis (loss of movement). The number of nerve fibres that are damaged is important as well. If a significant number of nerve fibres are still working, some mobility may be regained.

1.7.2 Scientific research has led to improved wheelchair design

Having a well designed wheelchair can greatly improve independence for people who are not able to walk. Many people who have to use wheelchairs are able to drive. Having to get a wheelchair in and out of the car can make it difficult to go out alone, however. Cars can be fitted with a wheelchair lift that lifts the wheelchair onto the roof of the car and lowers it when the destination is reached, but with limited mobility it can be difficult to get the wheelchair on and off the lift. Researchers in the US have come up with a solution — a laser-guided robot wheelchair that automatically gets itself on and off the wheelchair lift. To get into the car the driver presses a button and the driver's seat lowers to make it easier to get into the car. The driver then uses a remote control to direct the wheelchair to the back of the car. Once at the back of the car, the wheelchair uses radio signals and a laser to position itself onto the wheelchair lift. At the destination, the process is reversed so that the wheelchair is within easy access of the driver.

1.7.3 Research into rehabilitation

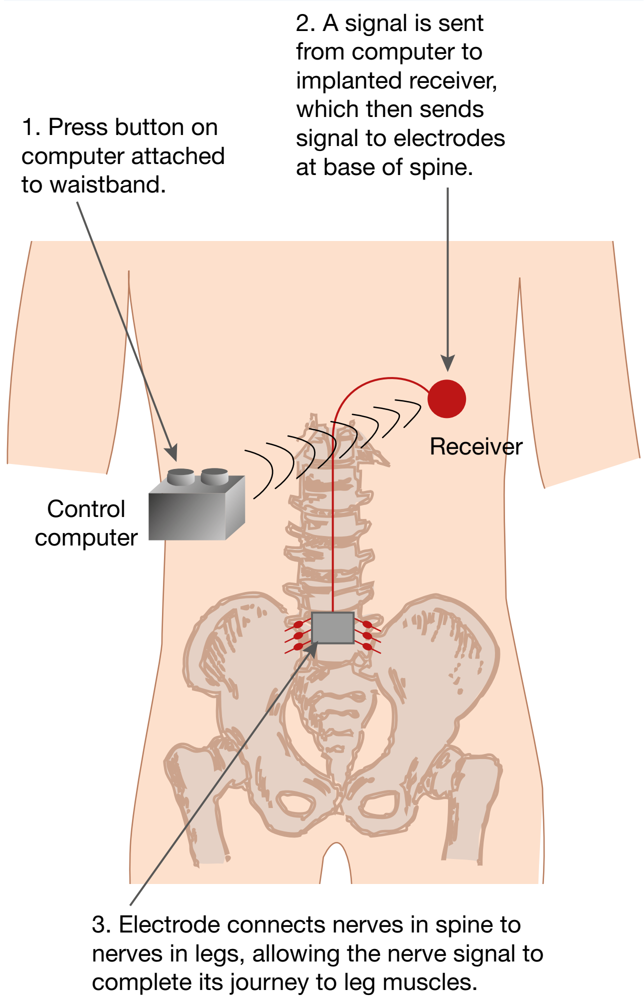
Anyone who has suffered a spinal injury will spend a great deal of time in rehabilitation. Depending on the degree of injury it may be possible for some patients to regain some movement in certain muscles. For the doctors and physiotherapists involved it is important to know when the rehabilitation process should start and what the program should involve.

For example, is it best to encourage patients to try to stand on crutches early after their injury, or is it best for the patient not to put any weight on their legs and use a wheelchair as much as possible? An experiment carried out on rats may assist physiotherapists to answer this question. In this experiment rats had their spinal cord crushed. Half the rats had small 'wheelchairs' strapped to their bodies to enable them to get around. The other half did not have the wheelchairs attached and could move around only by dragging themselves using their front legs. The rats with the wheelchairs strapped to their bodies recovered less limb function than those without. This has led researchers to hypothesise that there is a time window during which it is important to encourage patients to put weight on their legs. Further research might help them identify exactly when this time window is.

1.7.4 Artificial nerve impulses

Another area of scientific research that may assist people who have suffered a spinal injury is the use of electrodes to stimulate muscle cells artificially. In the 1990s UCL carried out a research project

The electrode system that allows Julie Hill to have some control of her leg muscles



into the use of electrodes to restore some movement and muscle control in patients who were paralysed as a result of a spinal injury.

Julie Hill was involved in this research project. Her spinal cord was severed in a car accident, leaving her with no sensation or muscle control below the waist. After a complex pioneering operation, Julie can now cycle, which has given her the opportunity to get daily aerobic exercise. The researchers were initially hopeful that the device would allow Julie to walk, but this proved to be more challenging than initially thought as walking takes a great deal of coordination between different muscles to provide the balance necessary to stay upright. Julie uses a reclining bicycle with 3 wheels. This requires less balance than a standard bicycle. The electrodes allow her to move her legs to pedal. She has electrodes attached to 12 nerves that run from the base of her spine to her legs. The electrodes are linked by wires to a small computerised receiver placed in her chest cavity. By pressing a button on a small computer attached to her waist, Julie is able to send pre-programmed radio signals to the implanted receiver, which then triggers responses in her leg muscles. The system acts rather like a complicated jump lead, connecting the nerve pathways on either side of the damaged spinal cord. Julie was first fitted with electrodes in 1998 and cycled for the first time in 2005. Reaching this milestone took a huge amount of work, determination and perseverance. A movie of her story has been made.

Julie's spinal cord was severed in a car accident. Modern technology has given her artificial nerve impulses. The significance is that Julie is being stimulated only by an implanted stimulator of the anterior lumbar nerve roots.

As well as allowing Julie to cycle, this technique could help spinal injury patients in other ways. For example, after spinal injury, a person may lose control of their bladder. Restoration of bladder control, which is possible in some cases, gives a sense of independence and dignity to a person. It also is important because bladder infection is a major cause of disease and death among paralysed people.

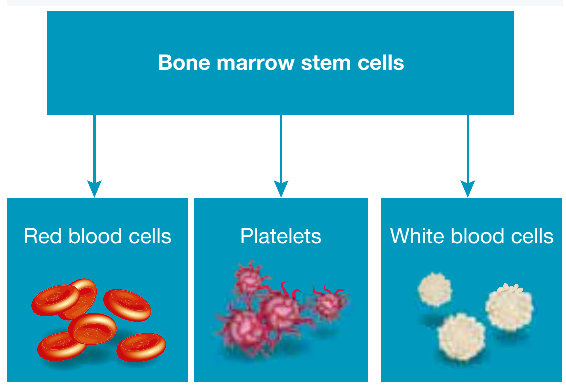
1.7.5 Stem cells may provide the answer

Stem cells are cells that are not fully differentiated. Under the right conditions, they can develop into various types of specialised cells. It may one day be possible to use stem cells to regrow damaged nerve cells to treat spinal injuries. Some stem cells are more versatile than others. Multipotent stem cells can differentiate into only a few cell types, whereas pluripotent stem cells can differentiate into any of the types of cells found in an adult organism, so they are of more interest to researchers. It should be noted, however, that stem cell research is a very rapidly advancing field of Science. Increasing the versatility of multipotent cells and producing stem cells from ordinary cells are two areas currently being researched by teams of scientists.

Multipotent stem cells

Multipotent stem cells are found in various parts of the body. They can differentiate into the types of cells that make up the tissue or organ where the stem cells exist. There are stem cells in the bone marrow that can develop into different kinds of blood cells (red blood cells and many types of white blood cells). Skin stem cells produce new skin cells to replace dead or damaged skin cells. Stem cells have also been obtained from the brain, muscle, the

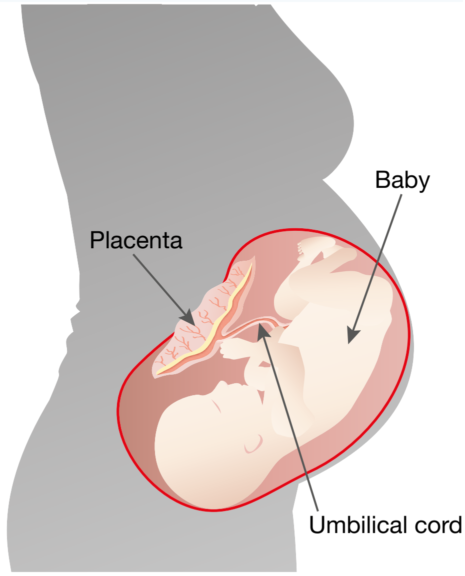
Bone marrow stem cells can develop into different types of blood cells.



pancreas and liver. The use of multipotent stem cells is generally not controversial as they can be obtained from consenting adult donors, but their use is limited as they can develop into only a few types of cells. Multipotent stem cells are used to treat certain medical conditions. Stem cells derived from the bone marrow are used to treat leukaemia and other blood disorders.

Another source of multipotent stem cells is umbilical cords. An umbilical cord is the cord through which an unborn baby gets nutrients and oxygen from its mother. It connects the baby to the placenta. When the baby is born, the placenta and the cord come out of the mother's body along with the baby. The blood from the cord contains stem cells that can develop into a few types of cells (mainly blood cells and cells involved in fighting disease) and are also being used to treat leukaemia and other blood disorders. Cord stem cells may, however, turn out to be more versatile than stem cells harvested from adults and may be useful to treat other conditions in the future.

Stem cells can be obtained from umbilical cord blood.

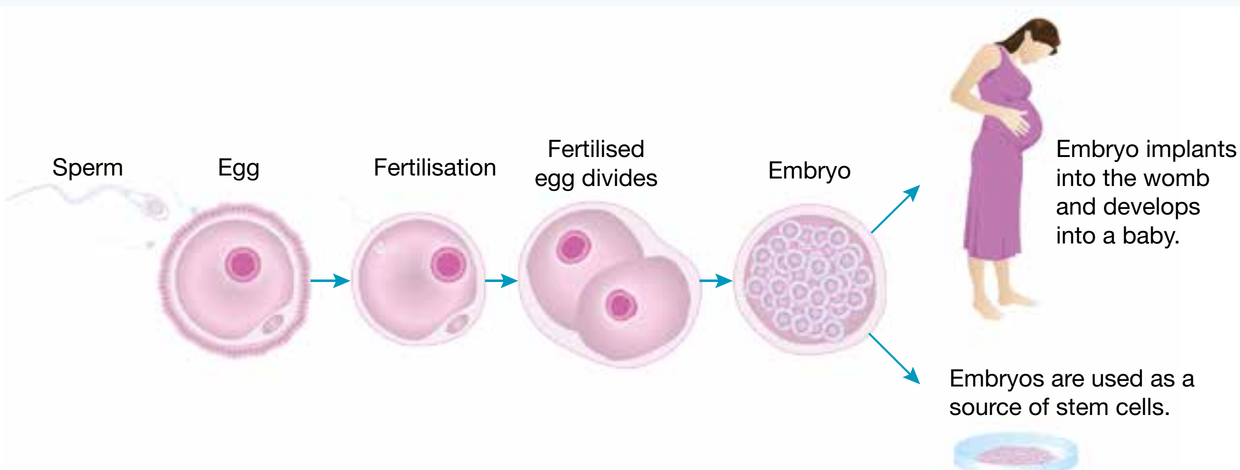


Some parents make the decision to freeze their baby's cord blood or cord tissue in case the baby or a relative gets sick later on and the stem cells are needed for treatment. This is a costly procedure. Alternatively, the cord blood can be donated to a cord blood bank, where it may be used to treat anyone who might benefit from it. With continued research, cord stem cells may one day be used to treat a range of life-threatening diseases.

Pluripotent stem cells

Embryonic stem cells are pluripotent — they can develop into all the different types of cells found in an adult organism. They are derived from embryos. An embryo is formed when a sperm cell fertilises an egg, which then divides into many cells. If fertilisation occurs in the body of a woman, the embryo can attach itself to the wall of the uterus and develop into a baby. When fertilisation occurs in a dish in a laboratory (in-vitro fertilisation, IVF), the embryo cannot develop into a baby unless it is then implanted into the uterus of a woman. However, because an in-vitro embryo has the potential to become a human, it is considered by many people to be human life. Removing the stem cells destroys the embryo, which is one of the reasons why the use of embryonic stem cells for research and medicine is controversial.

An embryo is the result of a sperm fertilising an egg. If this happens outside a woman's body, it is called in-vitro fertilisation.



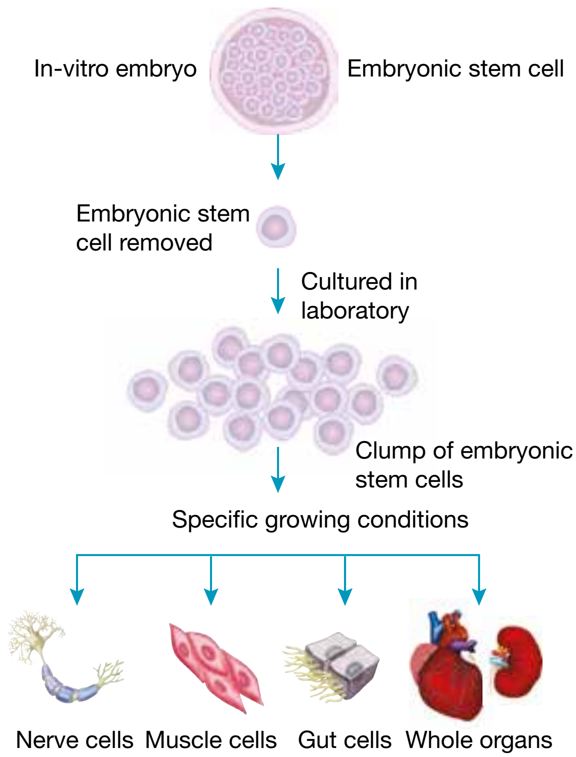
1.7.6 Why use embryonic stem cells?

When grown under the right conditions, embryonic stem cells can remain unspecialised and keep dividing. Embryonic stem cells that are allowed to clump can spontaneously develop into groups of specialised cells, such as muscle cells and nerve cells. It is possible to control the type of cells they will develop into by providing the stem cells with exactly the right growing conditions.

It might be possible to grow new nerve cells to replace the damaged nerve cells in people with a spinal cord injury. It may even be possible to make entire replacement organs from stem cells. Stem cells could also be used to treat a range of other diseases such as Alzheimer's disease, Parkinson's disease, diabetes and arthritis.

Researchers have been working on developing a treatment for spinal injury using stem cells. They have obtained promising results in rats. Injecting nerve cells produced from embryonic stem cells into the site of the spinal injury 7 days after the injury led to the recovery of some muscle function. Trials are now underway involving a small number of human volunteers. So far the stem cell injections have allowed the patients to regain some sensation to heat and touch that they had lost due to their injury.

Embryonic stem cells can develop into many different types of cells.



There are many good reasons for stem cell research, but there are also valid ethical arguments for not using embryonic stem cells. A solution would be an alternative source of stem cells that are just as versatile as embryonic stem cells, and many scientists are currently working towards this goal. In the meantime, the use of embryonic stem cells for research and medicine remains a controversial issue.

STEM CELLS

Professor Alan Trounson is an Australian scientist who has spent a great part of his working life perfecting the technique for creating embryos outside the human body. He was part of the team that produced the first baby conceived through IVF in Australia in 1980. He has also done a lot of work on embryonic stem cells. In 2000, his team showed that it was possible to produce nerve cells from embryonic stem cells.

From 2007 to 2014 he was the president of a Californian institute that specialises in stem cell research. It is the best-funded facility of its kind in the world, providing Trounson with the best facilities to move stem cell research forwards.

Questions

1. How long ago was the first baby conceived through IVF born?
2. Why is it particularly significant that Alan Trounson's team was able to produce nerve cells from embryonic stem cells?

1.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

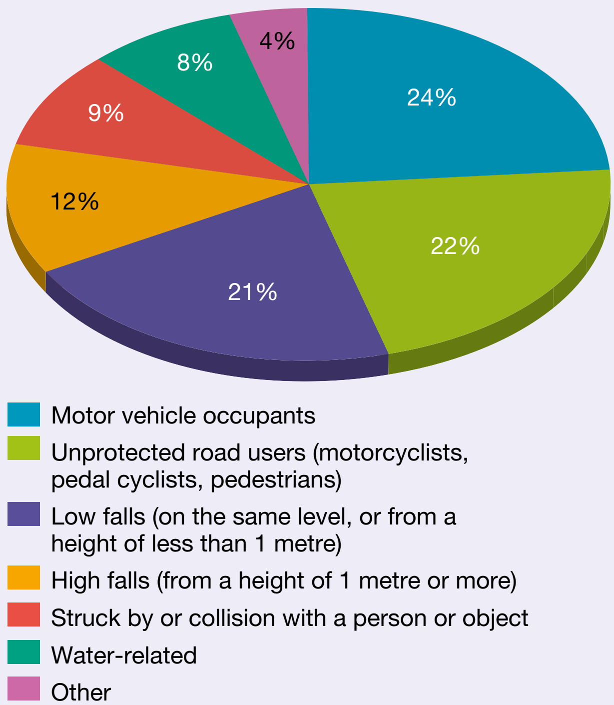
Remember

1. **Define** the terms spinal cord, paraplegia, quadriplegia, paralysis, stem cell and embryo.
2. **Distinguish** beatween multipotent and pluripotent stem cells.
3. **Identify** one use of stem cells derived from bone marrow in medicine.
4. **Explain** why some parents choose to have their baby's cord blood frozen.
5. **Outline** the work of an Australian scientist involved in stem cell research.

Think

6. Extract the answer to the following questions from the graph at right.
   (a) What are the two leading causes of spinal injury?
   (b) Of the seven categories of causes of spinal injury, how many do you think may involve a sports injury? Give a reason for your answer. Suggest which sports might have the highest risk of spinal injury.
7. **Explain** why an injury in the neck region of the spinal cord may result in quadriplegia whereas an injury in the lower back region of the spinal cord may result in paraplegia.
8. Imagine that you are on an ethics committee for a university. An ethics committee is a group of people that decide if experiments should be carried out on ethical grounds. **Discuss** whether you would allow scientists to do experiments that involve deliberately crushing the spinal cords of rats such as those described previously.
9. In the experiment where rats had wheelchairs strapped to their bodies:
   (a) **Identify** the control group.
   (b) **Outline** some variables that would have needed to be controlled.
   (c) **Explain** why researchers usually test medical procedures on animals such as rats before testing them on humans.
10. **Justify** why the use of multipotent stem cells is not as controversial as the use of embryonic stem cells.

Causes of spinal injury



Investigate

11. Draw a map to show the location and type of wheelchair access available at your school. Do the same for your local shopping centre. Are there any places it would be impossible to access in a wheelchair? Find out from your local council what regulations there are relating to wheelchair access to parks and public and commercial buildings.
12. **Investigate** some improvements to wheelchair design that have been made in the last 20 years.
13. Find out about wheelchair designs for particular sports such as wheelchair basketball and racing.
14. Choose one of the following — Parkinson's disease, type I diabetes, spinal cord injury, stroke, rheumatoid arthritis — and **investigate**:
    (a) what causes the condition
    (b) which cells stop working properly
    (c) what problems result
    (d) how stem cells might be useful in treating the problem.

Standard disability parking and access signs

15. Michael J. Fox and the late Christopher Reeve are two celebrities who have played an active role in supporting stem cell research in the US. **Investigate** why they became involved in this work and some of the initiatives they have been involved with.
16. Find out more about the work of Alan Trounson and some of the important discoveries he has been involved with.

Discuss

17. **Discuss** whether you would have your baby's cord blood frozen and kept for your own family's use if you have a child later in life.
18. Do you think research using embryonic stem cells should be legal in Australia? Write an exposition outlining your views.
19. Form six groups. Each group then nominates a student to act out one of the following roles (your teacher will assign one role per group). The other students in the group help the actor write their script. Each of the actors makes a brief presentation to the government (your class) about whether embryonic stem cell research should be allowed in Australia. At the end of the presentations, all the ministers (your classmates) will vote on whether to allow embryonic stem cell research in Australia.

Catholic priest: **You are against embryonic stem cell research. In accordance with your church's teachings, you believe that life begins at conception and destroying embryos to obtain embryonic stem cells is destroying a human life.**

Teenager: **You are paraplegic as a result of a car accident. You hope that stem cell research will lead to a treatment for spinal cord injury so that, one day, you can walk again.**

Mother of a child with type I diabetes: **You hope that stem cell research will lead to a cure for diabetes so that your daughter can have a healthy life free of diabetes.**

Scientist: **You would like to do embryonic stem cell research so that you can further your career and help a lot of people, perhaps finding a cure for a disease such as Parkinson's.**

Mother who has frozen embryos in storage at an embryo bank: **You and your husband could not have children naturally so you had fertility treatment. Ten of your eggs were fertilised with your husband's sperm. Two of these embryos were implanted in your uterus and you had twins. You do not want any more children, but eight frozen embryos remain. With your permission, these embryos could be used as a source of embryonic stem cells.**

The health minister: **You have your own opinion on embryonic stem cell research, but you also need to listen carefully to the views of the above people. After listening to their views, make a short speech to the government (your class) about stem cell research.**

20. Use the **Stem cell** weblink in the Resources tab to find out more about stem cells. Use the information presented in the animation to answer the following questions:
    (a) **Explain** the following statement: 'as an embryo develops the cells become increasingly specialised'.
    (b) Where are somatic stem cells found in adult humans?
    (c) Why do adults need somatic stem cells?
21. Use the **Stem cells and religion** weblink in the Resources tab and **investigate** the views of the major world religions on stem cell research.

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- **Explore more with this weblink:** Laser-guided wheelchair
- **Explore more with this weblink:** Stem cell elevator challenge
- **Explore more with this weblink:** Stem cells
- **Explore more with this weblink:** Stem cells and religion

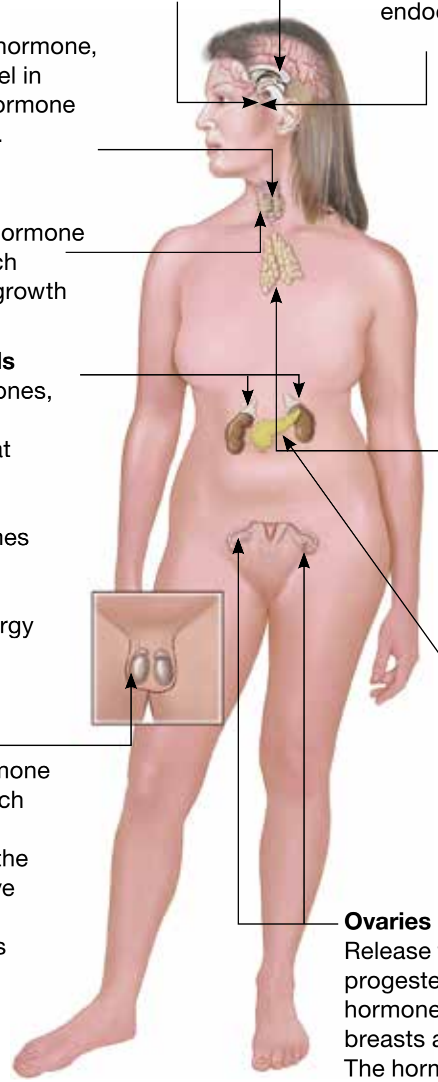
1.8 Slow control

1.8.1 Helpful hormones

Feeling stressed? ‘Butterflies’ in your stomach? Have you ever wondered what causes your body to react in a particular way to stressful situations? Hormones and glands play a part in the stress response.

The nervous system is not the only means of controlling and coordinating activities in your body. The endocrine system uses chemical messengers called hormones. They are produced in your **endocrine glands**

Endocrine glands and the hormones they produce



and are released directly into your bloodstream. Although hormones are carried to all parts of your body, only certain cells have receptors for particular hormones. It is a little like radio signals, which are sent out in all directions but are picked up only by radios attuned to a particular signal. These **target cells** are attuned to the hormones carried through your body and respond in a specific way.

Hormones control and regulate functions like metabolism, growth, development and sexual reproduction. The endocrine system responds to changes in variables detected by receptor cells and often acts using a negative feedback mechanism to counteract the initial change. The endocrine system also works with the nervous system to regulate your body's responses to stress. The effects of the endocrine system are often slower and generally longer lasting than those of the nervous system.

The diagram on the previous page shows some of the endocrine glands in the body and the hormones they produce.

1.8.2 Superhuman feats?

'Butterflies' in your stomach are the effects of a hormone called *adrenaline*. When you experience some kind of fright or stress, the adrenal gland releases adrenaline into your bloodstream. Not all parts of your body will be affected by its presence in the bloodstream. Adrenaline may cause your face to turn pale, your heart to beat faster and your muscular actions and energy levels to increase. This prepares your body to escape from, or fight your way out of, a dangerous situation. Adrenaline is often referred to as the 'fight or flight' hormone.

These runners have elevated adrenaline levels before their race.

Comparison of endocrine and nervous systems

Factor	Endocrine system	Nervous system
Speed of message	• Slow • Generally takes longer to have an effect	• Fast • Generally has a rapid effect
Length of response	• Often long lasting	• Usually short-lived
Spread of effect	• The hormones travel to all parts of the body via the bloodstream but affect only cells that have receptors for that particular hormone.	• Very localised
How message travels through the body	• In the bloodstream	• Along nerves
Type of message	• Hormone (chemical)	• Electrical impulse • Neurotransmitter (chemical)

HOW ABOUT THAT!

Following World War II, many starving men in concentration camps were discovered lactating (producing milk). The glands in men and women produce similar hormones but in very different amounts. Hormones are constantly being made and being broken down, mostly by the liver. In the starving men, the liver had shrunk enormously and was barely able to break down even the small amounts of hormones their bodies produced. So the level of some hormones actually rose to a point where breasts grew and milk was produced.

1.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the terms 'hormone' and 'endocrine gland'.
2. **Describe** how hormones travel throughout the body.
3. Why is it important that only cells with a receptor for a particular hormone are affected by the hormone?
4. **Construct** a three-column table with the headings 'Name of endocrine gland', 'Name of hormone' and 'Action of hormone' Use the information in the diagram Endocrine glands and the hormones they produce shown above to complete the table. Include all of the endocrine glands labelled in the diagram.
5. **Explain** why adrenaline is referred to as the 'fight or flight' hormone.

Think

6. **Explain** why the pituitary gland is sometimes referred to as the master gland.
7. The thyroid gland releases a hormone that increases metabolic rate. Suggest what the symptoms of an underactive thyroid gland might involve.
8. When would you expect the thymus gland to be most active?
9. Long periods of continued stress can increase the chance of heart disease. Use your knowledge of adrenaline and its effect on the body to **account for** this.

Investigate

10. Corticosteroids are a family of hormones released when the body is under stress. Find out about the role of these hormones and why they are sometimes prescribed to treat asthma.
11. **Investigate** what 'anabolic steroids' are.

1.9 Hormones and reproduction

1.9.1 Menstrual cycle

Some hormones play an important role in reproduction, such as controlling the menstrual cycle in women, sperm production in men and the development of secondary sex characteristics. Puberty is a time where hormone levels are changing and transforming the way the body appears and functions.

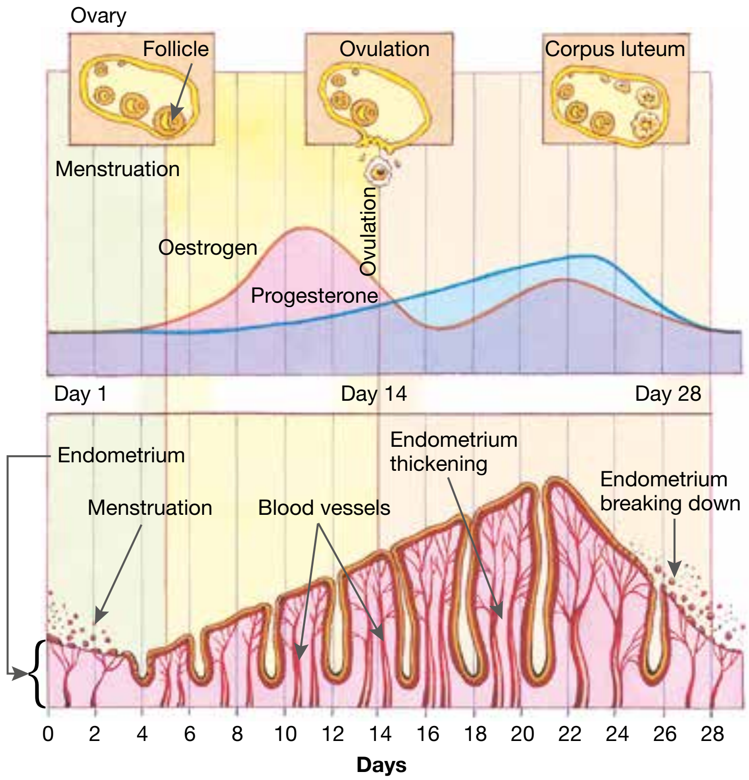
For about 5 days each month women menstruate (have their period). The time at which a woman has her first period is called menarche. The age at which this occurs varies greatly, but in Australia the average age of menarche is currently around 12 to 13 years of age. Women continue to have periods until they reach menopause, which is usually around their late forties to early fifties.

Menstruation is just one part of the menstrual cycle. When doctors and scientists talk about the menstrual cycle they refer to the start of a period as day 1 of the cycle. During menstruation the lining of the uterus is shed and the levels of the female hormones oestrogen and progesterone are at their lowest. After menstruation oestrogen levels rise and the lining of the uterus starts to thicken again so that it will be ready for an embryo if fertilisation occurs. In one of the ovaries an egg begins to ripen.

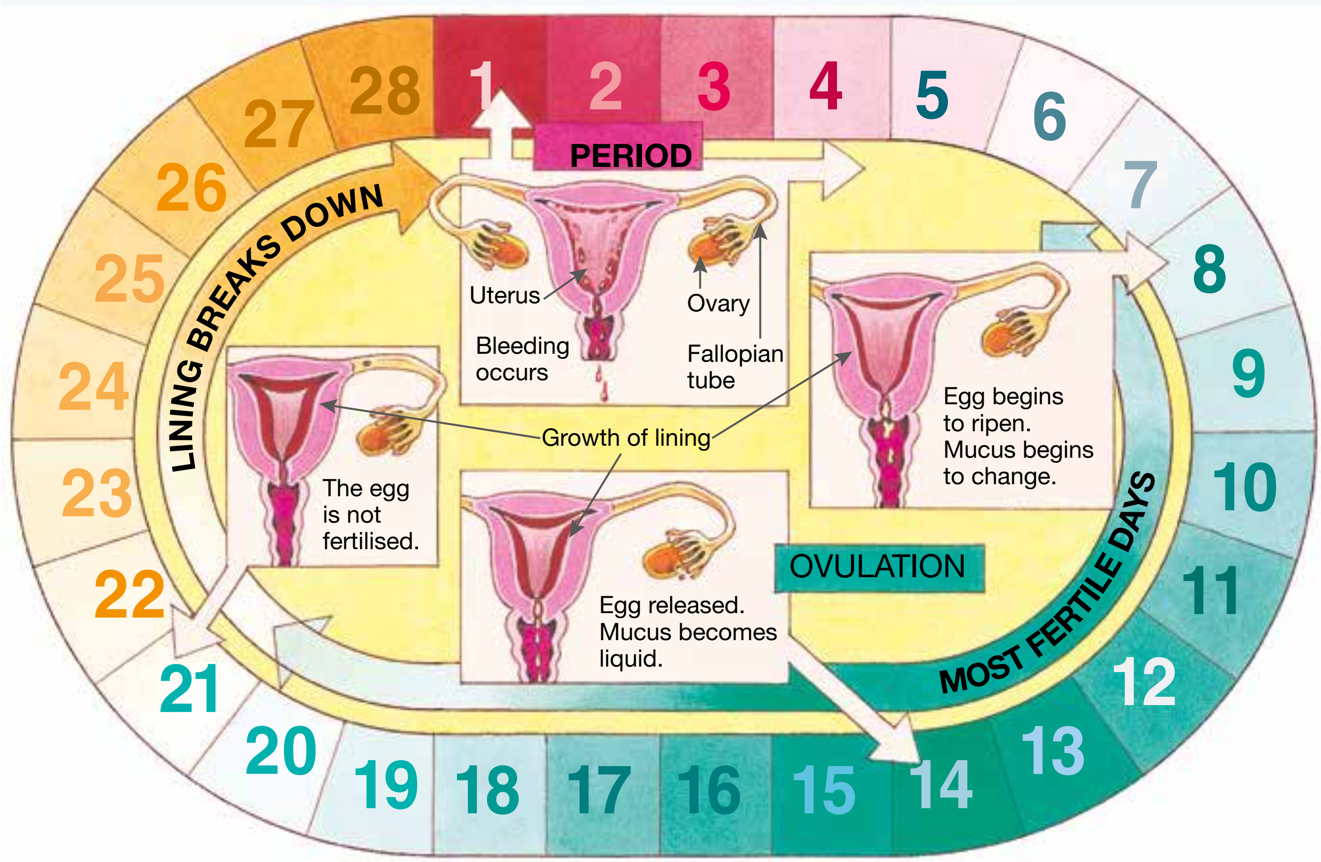
At ovulation a ripe egg is released from one of the ovaries. Ovulation occurs around day 14 of the menstrual cycle but this varies greatly between women. It is difficult to predict the time of ovulation simply by counting the days of the menstrual cycle. A more accurate estimate of the time of ovulation can be obtained by measuring and graphing body temperature. Temperature drops slightly before ovulation and then rises after ovulation has occurred. Hormone levels in blood, urine or saliva can also be used to indicate the time of ovulation. A hormone called luteinising hormone (LH) rises sharply just before ovulation.

What happens in the second half of the cycle depends on whether the egg becomes fertilised by a sperm cell. If the egg is not fertilised, it will not develop into an embryo and the endometrium (the lining of the uterus) will start to break down. The egg will eventually be passed out of the body. The hormone progesterone, another female sex hormone, gradually rises after ovulation.

Progesterone is involved in the menstrual cycle but it is also involved in pregnancy. Progesterone levels rise greatly during pregnancy. It prevents the uterus from contracting and pushing out the baby. Progesterone levels drop before childbirth and also just before menstruation. This allows the uterus to contract. Some women experience period pain. It is thought that in some cases this pain is due to the contractions of the uterus. The pain experienced in early labour is similar to this but much more intense.



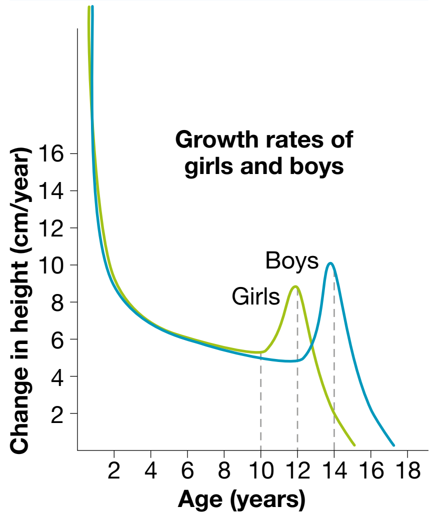
The menstrual cycle



1.9.2 Secondary sex characteristics

Secondary sex characteristics are features that are present only in adults, for example, a lion's mane and a peacock's tail are secondary sex characteristics. In humans, secondary sex characteristics appear at the time of puberty. In women they include breasts, a wider pelvis, changed distribution of body fat (more fat is deposited around the bottom, hips and thighs) and underarm and pubic hair. In males, secondary sex characteristics include changes to the larynx that result in a lower voice, facial, underarm and pubic hair, increases in muscle and bone mass, height and penis size, and broadening of the shoulders. The development of secondary sex characteristics is stimulated by increased levels of oestrogen in women and testosterone in men. Around the time of puberty both boys and girls also experience a growth spurt — a rapid increase in height. This is shown in the graph at right.

Both boys and girls experience a growth spurt around the time of puberty.

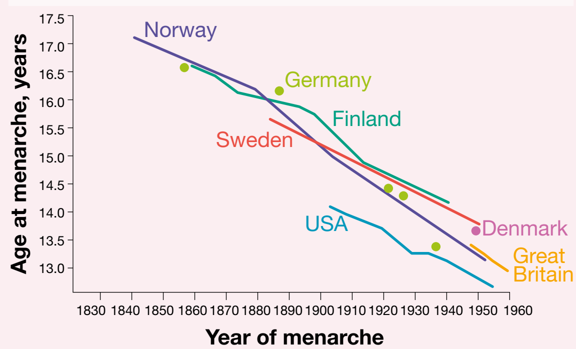


HOW ABOUT THAT!

Over the last two centuries, the age at which girls reach puberty has been decreasing. The following graph shows how the age at which girls have their first period (menarche) has changed over time in a number of countries.

Many factors affect the age at which girls reach menarche. Studies have shown that girls have their first period earlier if they live at sea level rather than at high altitudes. A diet high in fat and proteins also results in earlier menarche and poor nutrition can delay it. There have even been studies that show that girls that live with their genetic father reach menarche later on average than girls that live with just their mum. Girls who live with a stepdad, on average, reach menarche the earliest. No one is sure exactly how it works but it is thought that pheromones may be involved.

The average age of menarche has decreased over the last two centuries.



1.9.3 Pheromones — smells like love

Chemicals called pheromones can play an important role in communications between members of the same species. This type of communication makes it very easy for animals to locate a mate, even in sparsely populated areas.

When a female dog is about to ovulate, she comes 'on heat'. During this time she releases a pheromone into her urine to notify male dogs that she is ready for mating. Likewise, female moths use scented chemicals that sexually attract male moths from as far away as 8 kilometres.

Pheromones are probably important in humans too.

1.9.4 Oxytocin — the cuddle chemical

Oxytocin is a hormone involved in labour and breastfeeding, and it causes the uterus to contract. When labour is induced (started artificially) an oxytocin drip is used. In breastfeeding oxytocin causes the milk to be released after the baby starts sucking.

Oxytocin is also called the cuddle chemical, as it is released when mothers cuddle their babies and when humans have ‘warm contacts’ (a supportive hug from a parent, or a husband and wife holding hands, for example). Oxytocin is thought to help humans form bonds with other people such as the bond between a mother and her baby or between a husband and wife. In recent years tests have been conducted to determine what happens when oxytocin is given to people. From these experiments it was found that oxytocin seemed to improve a person’s ability to recognise faces and to interpret other people’s feelings. Studies in rats show that if the oxytocin receptors in the brain are blocked rats stop looking after their young and can no longer recognise other rats.

Oxytocin is a hormone that is released when a baby suckles. It triggers milk ‘let-down’, the release of milk from the breast.

HOW ABOUT THAT!

A Swiss zoologist, Claus Wedekind, carried out an experiment to find out if pheromones might be involved in determining whether a woman will find a particular man attractive. He asked men to wear a T-shirt for two nights and return it unwashed. The T-shirts were placed in containers with smelling holes and women were asked to smell them and describe the odour. The women described and ranked the smells differently; however, they preferred the smells of the T-shirts worn by the men that were most different to them in terms of genes involved in immunity. Perhaps by trusting their noses women might naturally select partners whose genetic makeup will contribute to producing babies with strong immune systems.

The T-shirts worn by the men were placed inside boxes with smelling holes and women were asked to smell them and rate the odour.

HOW ABOUT THAT!

Pheromones are an important form of communication for ants. When ants find a food source they lead other ants to the food by leaving a trail of pheromones. A squashed ant releases pheromones that act as a warning signal to other ants.

1.9 Exercise: Remember and think

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Remember

1. Match each term on the left in the table with one of the definitions at right.

Term	Definition
(a) Menstruation	(i) Male sex hormone
(b) Menarche	(ii) A hormone that triggers ovulation
(c) Menopause	(iii) A hormone involved in bonding
(d) Ovulation	(iv) Period
(e) Endometrium	(v) The female sex hormone that is at its highest level prior to ovulation
(f) Testosterone	(vi) When an egg is released from an ovary
(g) Oestrogen	(vii) When women stop having regular periods
(h) Luteinising hormone	(viii) Scented chemicals involved in communication between members of the same species
(i) Progesterone	(ix) Lining of uterus
(j) Pheromones	(x) Time at which a woman has her first period
(k) Oxytocin	(xi) The levels of this hormone increase in the second half of the menstrual cycle.

2. Around which day of the menstrual cycle do the following events occur:
   (a) ovulation?
   (b) first day of period?
3. **Identify** the hormones responsible for triggering sperm production in males and ovum development in females.
4. **Describe** the changes in oestrogen and progesterone levels throughout the menstrual cycle.
   (a) Which hormone is found in the highest concentration just before ovulation?
   (b) Which hormone is found in the highest concentration when the uterine lining is thickest?
   (c) At which time would the lining provide the best 'home' for a fertilised egg?
5. **Classify** the following secondary sex characteristics as belonging to males, females or both:
   (a) Low voice
   (b) High hip to waist ratio
   (c) Pubic hair
   (d) Facial hair
   (e) Broad shoulders
   (f) Low hip to waist ratio
   (g) Underarm hair.
6. What does it mean when a dog is 'on heat'?

Think

7. **Deduce** on which days of a menstrual cycle a woman is most likely to become pregnant if she has sexual intercourse. Is it possible for a woman to fall pregnant outside this time? **Explain** your answer.
8. **Explain** why it is important for mothers to bond with their babies.

Skill builder

9. Study the graph showing the growth rates of boys and girls.
   (a) **Deduce** which two years of their lives children grow the fastest.
   (b) **Identify** the average age at which girls and boys experience a growth spurt. **Explain** why not all children will experience a growth spurt at exactly these ages.
   (c) At what age, on average, do girls and boys reach their maximum height?
   (d) What is the average growth rate of a 9-year-old girl? If a 9-year-old girl was 130 cm tall, **calculate** what you would expect her height to be a month ($\frac{1}{12}$ of a year) later, assuming that she is growing at the average growth rate for a 9-year-old.
   (e) **Compare** a 10-year-old boy and a 10-year-old girl. If they both measured 125 cm at age 10, who would be taller at age:
      (i) 13?
      (ii) 17?
      Explain your answer. Assume the boy and the girl are following the average growth rates shown in the graph.

10. Study the graph showing how the average age of menarche has changed over the last 2 centuries.
   (a) **Describe** the general trend shown by the data displayed on the graph.
   (b) For which country has data been collected over the greatest length of time?
   (c) **Compare** the data for the USA to the data for European countries. Suggest possible reasons for any differences in the data.
   (d) Data is not shown for dates after 1960. If the trend shown in the graph had continued at the same rate, what would be the average age of menarche for girls living in Norway today? Assuming that the data for Australian girls is similar to the data for girls growing up in Norway, has the trend shown in the graph continued?

Investigate

11. Design an experiment to test the hypothesis that a particular pheromone can make men more attractive to women.
12. Oxytocin might have benefits for people who suffer from certain forms of autism. Find out what autism is. Suggest why oxytocin might be beneficial for autistic children.

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Complete this digital doc: Worksheet 1.3: The menstrual cycle (doc-12737)

Complete this digital doc: Worksheet 1.4: Puberty (doc-12738)

1.10 Review

1.10.1 Systems keeping cells alive

- **explain** why multicellular organisms require specialised organs and systems. **1.2**
- **recall** examples of tissues, organs and systems in humans. **1.2**
- **recall** the systems involved in providing cells with their requirements and removing waste. **1.2**
- **define** the term homeostasis. **1.3**
- **distinguish** between negative and positive feedback mechanisms. **1.3**
- **describe** an example of negative feedback to maintain homeostasis. **1.3**
- **outline** the role of the kidneys in maintaining water balance. **1.3**

1.10.2 The nervous system

- **recall** 4 types of receptor cells. **1.4**
- **describe** the structure of the eye. **1.4**
- **outline** the function of the nervous system. **1.5**
- **describe** the structure of nerve cells. **1.5**
- **contrast** reflex reactions and actions under conscious control. **1.5**
- **describe** the structure and function of the brain. **1.6**

1.10.3 The endocrine system

- **outline** the function of the endocrine system. **1.6**
- **recall** the main glands of the endocrine system and some of the hormones they produce. **1.6, 1.8**
- **compare** and contrast the nervous and endocrine system. **1.5, 1.8**
- **outline** the stages of the menstrual cycle. **1.9**
- **recall** some of the hormones involved in reproduction and the development of secondary sex characteristics. **1.9**

1.10.4 Scientific research

- **describe** some applications of science in the treatment of spinal injuries. **1.7**
- **outline** some potential benefits of stem cell research. **1.7**
- **justify** why the use of embryonic stem cells for scientific research is controversial. **1.7**

Individual pathways

ACTIVITY 1.1	ACTIVITY 1.2	ACTIVITY 1.3
Investigating control systems doc-10631	Analysing control systems doc-10632	Investigating control systems further doc-10633

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online only

FOCUS ACTIVITY

Luke has a pet bearded dragon called Mr Lizard. Luke is also a wiz at electronics. Luke is going on holidays for a week and he would like to make modifications to Mr Lizard's tank so that all his pet's needs will be catered for while he is on holidays.

(a) Use the information in the Resources tab to draw a diagram showing how to modify the tank.

(b) Compare the modified tank to the nervous system. Which parts correspond to the receptors, sensory nerves, central nervous system, motor nerves and effector organs?

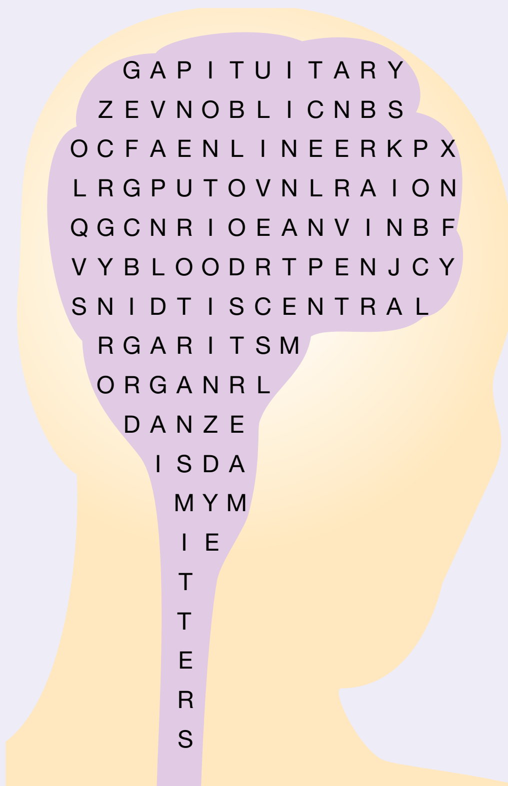
Access more details about focus activities for this topic in the Resources tab (doc-10630).

assesson

1.10 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

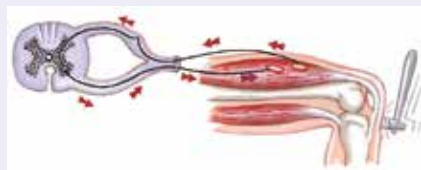
1. Underline the incorrect terms in each sentence. Replace them with the correct term and then find the correct term in the word puzzle. Write definitions of the incorrect words you replaced.
   (a) The neuron carries hormones to target cells.
   (b) The master gland of the endocrine system is the adrenal gland.
   (c) The brain and spinal cord make up the peripheral nervous system.
   (d) Organelles carry messages across synapses.
   (e) Each molecule has tissues which carry out particular functions.
   (f) Reflex actions and negative feedback mechanisms are examples of learned behaviour.
   (g) Hormones are constantly being broken down, largely by the brain.
2. Body systems need to work together to provide cells with their requirements. **Identify** two body systems that work together to:
   (a) deliver oxygen to cells
   (b) deliver glucose to cells
   (c) remove carbon dioxide from cells (and the body)
   (d) remove nitrogenous waste from cells (and the body).



3. Complete the table below.

Organ	Type of receptors	What do these receptors detect?
Eye		
Ear		
Nose		
Skin		

4. (a) **Identify** the type of neuron shown at right and outline its role in the nervous system.
   (b) Which of the parts A, B, C, D or E, is:
   (i) the nucleus?
   (ii) the myelin sheath?
5. In the human nervous system:
   (a) What do the letters CNS stand for?
   (b) What is the CNS composed of?
   (c) What do the letters PNS stand for?
   (d) What is the PNS composed of?
6. The figure at right shows the nervous pathway of the ‘knee-jerk reaction’.
   (a) How do you know that the knee-jerk reaction is a reflex response?
   (b) What is the stimulus for the knee-jerk reaction?



7. Mix and match the following table so that the description or role matches the correct part of the nervous pathway.

Part	Description or role
(a) Neuron	(i) Chemical released into the gap between nerve cells
(b) Synaptic cleft	(ii) A nerve cell
(c) Receptor	(iii) Site of the nucleus of a nerve cell
(d) Axon	(iv) Senses changes in surroundings
(e) Neurotransmitter	(v) Carries an impulse to the next neuron
(f) Cell body	(vi) Space between neurons

8. Label the human brain at right with the name and function of each structure.

9. Copy and complete the table below.

Gland	Hormone	Function
		Controls overall growth and development
Thyroid		
		Stimulates production of white blood cells
	Adrenaline	
		Allows cells to take up glucose from the blood
Testes		

10. **Construct** a timeline of the menstrual cycle. Label the following:
    (a) start of menstruation
    (b) end of menstruation
    (c) ovulation
    (d) lining of uterus thickens
    (e) uterus lining is shed.
11. List at least 4 hormones that are involved in reproduction and **outline** the function of each of these.

Test yourself

12. Which of the following statements is correct?
    (a) In the nervous system messages travel in the form of electrical signals only.
    (b) In the nervous system messages travel in the form of neurotransmitters only.
    (c) Hormones travel from glands to effectors in the bloodstream.
    (d) Hormones travel along nerves. **(1 mark)**
13. Which endocrine gland secretes hormones that regulate the function of a number of other endocrine glands?
    (a) The pituitary
    (b) The hypothalamus
    (c) The thyroid gland
    (d) The adrenal glands **(1 mark)**
14. In which of the following organs are chemoreceptors located?
    (a) Eye
    (b) Nose
    (c) Ear
    (d) Lips **(1 mark)**
15. Which row of the table contains correct information?

	Receptor cells	Sensory nerves	Motor nerves	Effector organs
A	Detect stimuli	Relay messages from receptor cells to the CNS	Relay messages from CNS to effector organs	Bring about response to stimulus
B	Bring about response to stimulus	Relay messages from CNS to effector organs	Relay messages from receptor cells to the CNS	Detect stimuli
C	Detect stimuli	Relay messages from receptor cells to the CNS	Bring about response to stimulus	Relay messages from CNS to effector organs
D	Detect stimuli	Relay messages from CNS to effector organs	Relay messages from receptor cells to the CNS	Bring about response to stimulus

16. Which hormone acts on the nephrons in the kidney to reduce the amounts of water excreted from the body?
    (a) glucagon
    (b) insulin
    (c) ADH
    (d) FSH
17. Using maintenance of a constant body temperature as an example, **explain** what a negative feedback mechanism involves. **(4 marks)**
18. **Describe** one area of scientific research that may assist people who have a spinal injury. **(3 marks)**

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Complete this digital doc: Worksheet 1.5: The body under control: puzzle (doc-12739)

Complete this digital doc: Worksheet 1.6: The body under control: summary (doc-12740)

TOPIC 2
Medical science

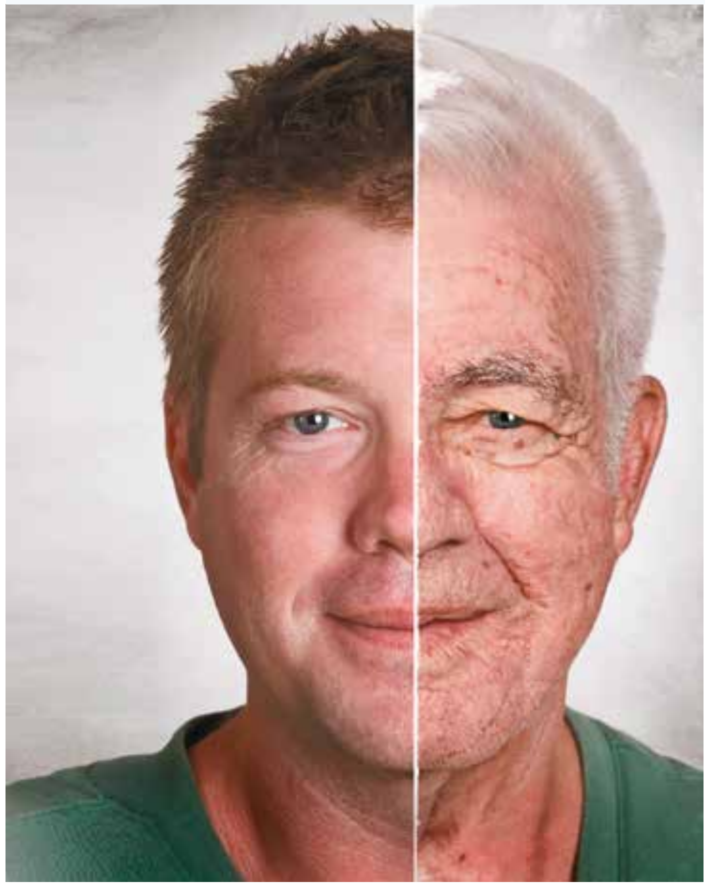
2.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

2.1.1 Why learn this?

In 1955 the average life expectancy at birth was just 48 years. Today it is about 70 years. In Australia it is even higher. Advances in Science and medicine have allowed humans to live longer and to continue to lead active, healthy lives into old age. Technological advances have enabled researchers to learn more about the cause of disease and in turn this has led to the development of new technology to address health issues. In this topic you will be learning about infectious and non-infectious diseases and the body's natural defences against infection. You will also be learning about the role of medical science in addressing problems in society.

Modern medicine has increased the human life span. The man on the left below is aged about 48, the average life expectancy 50 years ago. The image on the right shows his age at today's average life expectancy age.



LEARNING SEQUENCE

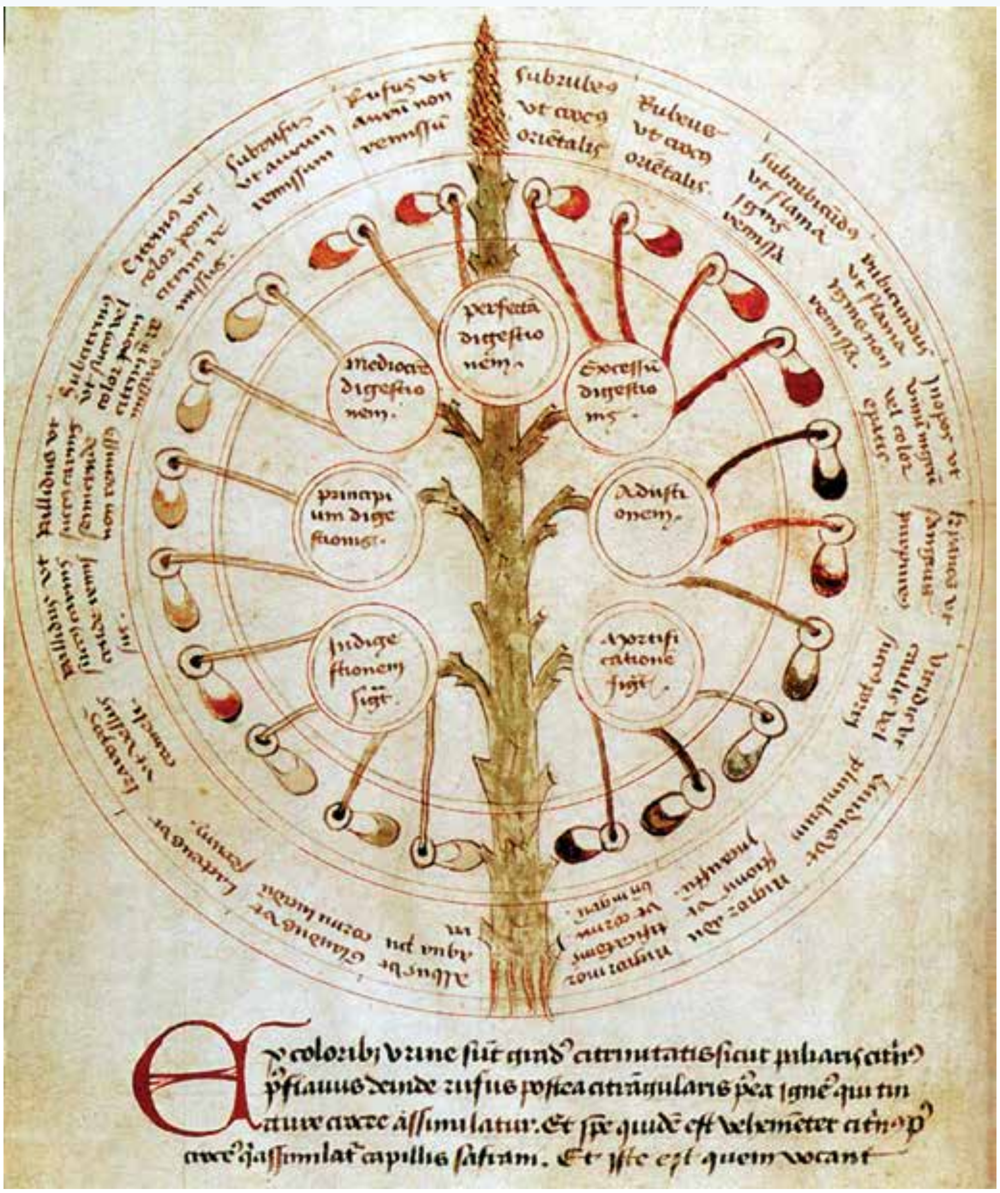
2.1.2 Medieval medicine

The Middle Ages (AD 500–1500) were a time of hardship, deadly disease and wars in which only about 50% of children reached the age of 15. Many of the survivors died in their twenties and thirties. A visit to the doctor was probably just as likely to make a person sicker rather than improve health, and if you had a sore tooth you were likely to be sent to the barber to have the tooth pulled out!

Medieval physicians advised their patients how to live healthy lifestyles, and used their training in mathematics and astronomy to map out healthy and sickly times. They also worked closely with apothecaries, who sold medicinal plants. Sometimes these plants were used to create medicines. Medieval women made many of their family's medicines. They used seeds, stems and leaves of herbs, trees and flowers. Some medicines even used animals or animal products.

Many medieval physicians considered that testing 'the waters' (urine) was an effective method in the diagnosis of disease. Scribes would note the colour, cloudiness or sediment of the urine and charts were used to match these features to particular diseases. Sometimes blood samples were collected, which may have been tasted to detect a diagnostic sweetness or bitterness.

A fifteenth-century diagram showing possible colours of urine to help doctors diagnose diseases



Medieval barbers not only cut men's hair and shaved their faces but also performed minor surgery, such as removing rotten teeth and bloodletting. The red and white striped pole often associated with barbers was a symbol that they let (released) blood, with the white stripes representing the bandages over the cuts.

Not only barbers were involved in bloodletting — this widespread medieval treatment was also performed by doctors and surgeons. Medical texts of the time talked about balancing humours and showed which veins to cut to release each humour and cure different illnesses. Leeches were also applied to the skin to suck out poisons or bad blood from wounds.

Surgeons also used cupping and cauterising to treat disease. Cupping involved placing hot metal glasses or cups on a patient's cut skin, in the belief that poisons would be released from the body into the cup. To cauterise wounds or help heal internal disorders, surgeons would burn the tissues with red-hot irons or boiling oil.

Leeches were used to treat disease during medieval times.

2.1 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

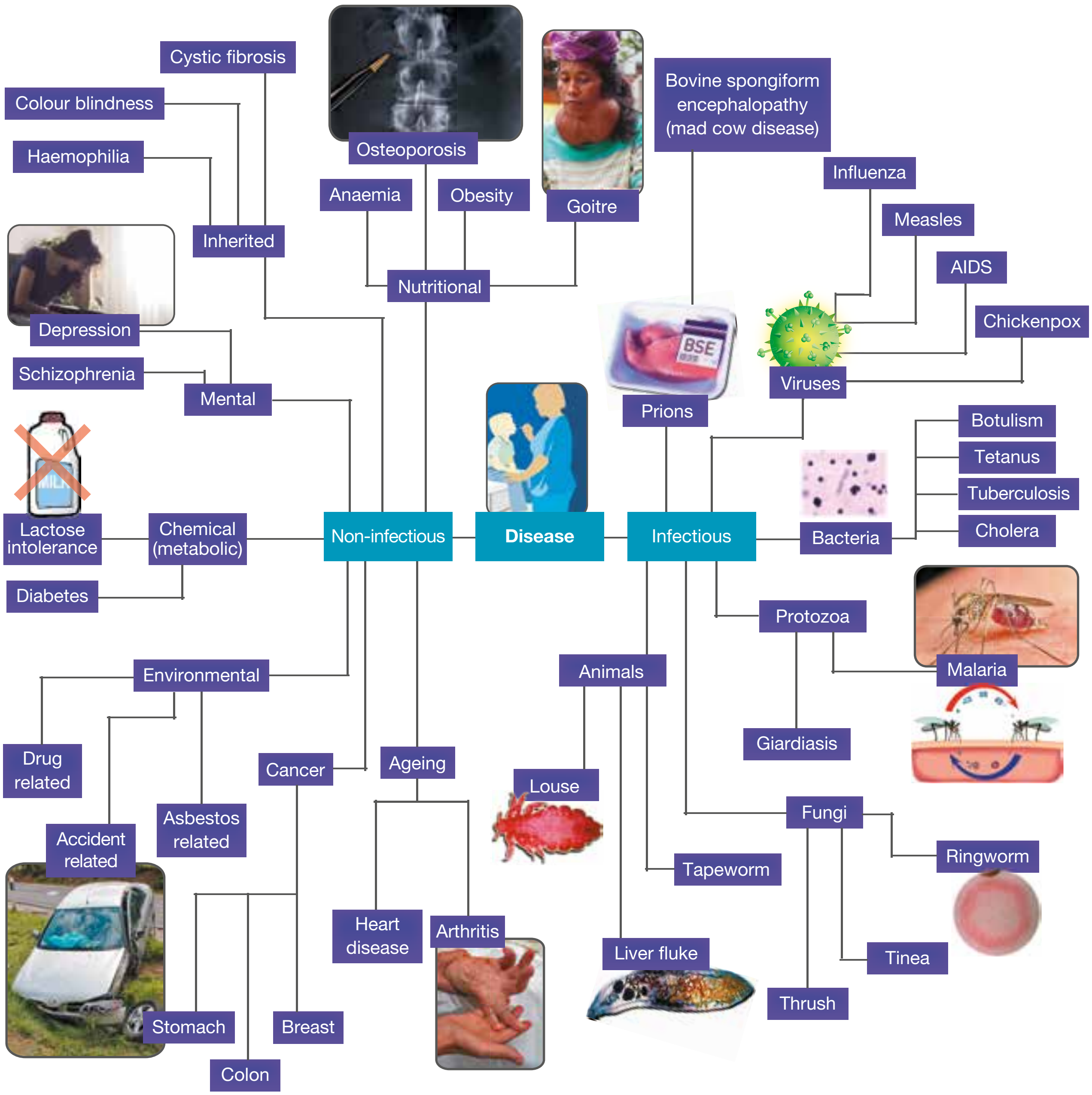
1. Is knowledge of astronomy considered an important part of medical training today?
2. What is an apothecary?
3. Some of the potions made using ingredients purchased from an apothecary would have contributed little to improving the health of the patient. Can you think of products available today that people buy to improve their health even though there is no scientific evidence to suggest the product actually works?
4. In the treatment of most diseases bloodletting would be not only ineffective but it might actually make the patient sicker. **Explain** why opening a blood vessel and allowing blood to pour out could make someone sick.
5. Bloodletting is still used today in the treatment of haemochromatosis, polycythemia vera and porphyria cutanae tarda. Find out about these diseases and why bloodletting is an effective treatment.

2.2 Catch us if you can

2.2.1 Classifying diseases

Diseases can be classified into two main categories: infectious and non-infectious. Infectious diseases are caused by pathogens — disease-causing organisms. There are different types of pathogens including some bacteria, viruses and fungi. The pathogen lives in or on the body of the sick person and under the right conditions it can be transmitted from one person to another, so infectious diseases are also called transmittable diseases. Non-infectious diseases are not caused by pathogens and cannot be transmitted from one person to another. You cannot 'catch' a non-infectious disease from another person. The diagram on the next page shows one way of classifying diseases.

Classifying diseases



2.2.2 Meet the pathogens

Pathogens are disease-causing organisms. They are parasites: they live in or on another organism (the host) and have a harmful effect on their host. Some pathogens are large enough to be seen without a microscope. Tapeworms, head lice and liver flukes are examples of pathogens you can see without a microscope. Most pathogens are tiny and cannot be seen without a microscope. Many diseases are caused by single-celled bacteria, protozoa or fungi. Viruses and prions are not even big enough to be seen with a light microscope but they can cause serious illness as well. When you 'catch' a disease from another person the pathogen they are carrying invades your body. The table on the next page summarises key information about the different types of pathogens.

Type of pathogen	Description	Typical size	Example of diseases
Bacteria	Bacteria are single-celled organisms whose DNA is not contained inside a membrane-bound nucleus. 	0.2–5 μm	Scarlet fever, meningococcal meningitis, impetigo, tuberculosis, leprosy, some throat and middle ear infections
Viruses	A virus consists of a piece of DNA or RNA wrapped in a protein coat. Viruses cannot reproduce unless inside a host cell. 	20–300 nm	AIDS, influenza (the flu), hepatitis, SARS, measles
Protozoans	Protozoans are single-celled organisms whose DNA is inside a membrane bound nucleus. 	2–200 μm	Malaria, toxoplasmosis, amoebic dysentery, cryptosporidium, malaria
Fungi	Fungi are made up of one or more cells that have a cell wall, true nucleus and no chloroplasts. Athlete's foot (shown in the picture at right) is caused by a fungus. 	Varies from 50 μm to much larger (e.g. mushrooms)	Thrush, ringworm, athlete's foot, onychomysis (a fungal infection of the to enails)
Macroparasites	Macroparasites can be seen without a microscope. 	Size varies greatly but can be seen without a microscope	Head lice infestation, flea infestation, elephantitis (caused by a nematode worm)
Prions	Prions are thought to be incorrectly folded proteins. 	10–200 nm	BSE (bovine spongiform encephalitis, also known as mad cow disease), fatal familial insomnia, Creutzfeldt–Jakob disease, kuru

Note: 1 μm = 0.001 mm = 0.000 001 m
1 nm = 0.000 001 mm = 0.000 000 001 m

2.2.3 Can't catch us

The seven main types of non-infectious diseases are related to:

- nutrition, including overeating, undereating and eating an unbalanced diet
- ageing, the gradual breakdown of body tissues
- cancer, the multiplication of body cells at an abnormal rate
- inherited disorders, which are passed on from your parents' genes
- mental disorders, with a variety of causes including chemical deficiencies, stress and trauma
- chemical deficiencies that result in metabolic disorders
- environmental diseases resulting from exposure to poisons, asbestos, fire, accidents and drugs.

2.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Distinguish** between the causes of infectious and non-infectious diseases.
2. **Recall** seven types of non-infectious diseases.
3. (a) **Classify** the following diseases as infectious or non-infectious: lung cancer, AIDS, Down syndrome, the flu, head lice infestation, diabetes, laryngitis, malaria, measles, cystic fibrosis, depression, chickenpox, hepatitis A, tinea (athlete's foot), BSE (mad cow disease). Present your answer in the form of a table.
   (b) For the diseases that you classified as infectious, indicate whether they are caused by a macroparasite (M), protozoan (P), fungi (F), bacteria (B), virus (V) or prion (P).
4. Organise the pathogens listed in the table on the previous page in order from smallest to biggest.
5. Use the mind map Classifying diseases to **distinguish** between the causes of:
   (a) goitre and arthritis
   (b) haemophilia and anaemia
   (c) AIDS and malaria
   (d) tinea and chickenpox.

Think and investigate

6. **Explain** why nutritional diseases are not classified as infectious diseases.
7. Until the middle of the twentieth century, infectious diseases killed many more people than non-infectious diseases. However, since about 1930, in the developed countries of Australia, North America and Europe, more people have died from non-infectious diseases. **Account for** this change.
8. The biggest killer of Australians in 2006 was heart disease. **Explain** how diseases of this kind, such as heart attacks, might be related to nutrition.

Research

9. (a) **Investigate** the cause, symptoms and methods of prevention for one of the following diseases: osteoporosis, schizophrenia, haemophilia, anaemia, arthritis, heart disease, lung cancer, skin cancer.
   (b) **Report** your findings back to your team or class in a PowerPoint presentation, visual thinking tool or poster.
   (c) In your team, **discuss** with others any ways in which the community or government may be involved in reducing the impact or frequency of these diseases.
10. Fatal familial insomnia is a disease caused by prions.
   (a) **Investigate** the symptoms of this disease.
   (b) Even though fatal familial insomnia is caused by prions, it is also considered to be a hereditary disease. Find out why.

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Complete this digital doc: Worksheet 2.1: Infectious diseases (doc-12741)

Complete this digital doc: Worksheet 2.2: Non-infectious diseases (doc-12742)

2.3 Healthy living

2.3.1 What's killing us?

Lifestyle factors including smoking, drinking alcohol, lack of exercise and a poor diet are risk factors that are contributing to the premature death of people throughout the world. Scientific research can help determine which lifestyle factors are the biggest threat to health and provide data that may be useful in giving advice and providing guidelines about healthy living.

The table following shows some of the leading causes of deaths for men and women worldwide and the graph below shows the leading causes of death in Australia.

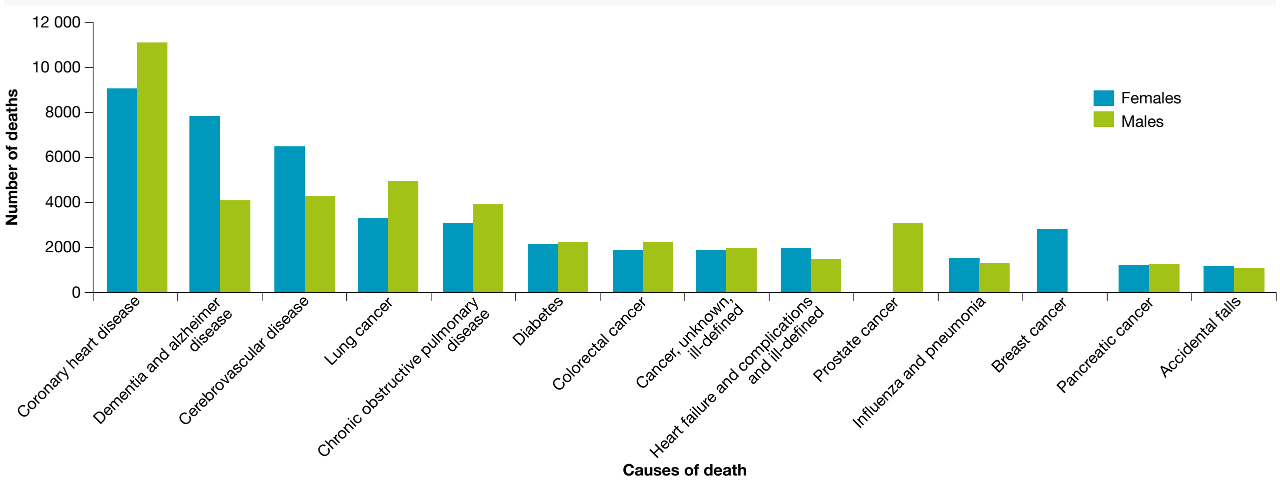
When comparing the global and Australian data it is important to remember that globally the life expectancy for females is 73.3 years and for males it is 67.5 years, whereas in 2015 the average Australian female had a life expectancy of 84.5 years and the average Australian male's life expectancy was 80.4 years. That figure has been increasing steadily, although there are concerns that increased rates of obesity might eventually reduce life expectancy in wealthy nations such as Australia and the US. In some parts of the world, particularly where a large proportion of the population is infected with HIV, the virus that causes AIDS, life expectancy is much less than in Australia. More information about AIDS is included in subtopic 2.7.

Leading causes of death worldwide

Cause	Percentage of deaths
Ischaemic heart disease	12.8
Stroke and other cerebrovascular disease	10.8
Lower respiratory infections	6.1
Chronic obstructive pulmonary disease	5.8
Diarrhoeal diseases	4.3
HIV/AIDS	3.1
Trachea, bronchus, lung cancers	2.4
Tuberculosis	2.4
Diabetes mellitus	2.2
Road traffic accidents	2.1

Source: http://who.int/mediacentre/factsheets/fs310/en/

Leading causes of death in Australia



One trend is clear though; many people are dying from diseases that are linked to lifestyle factors. Cardiovascular diseases including stroke and heart attack are leading causes of death both in Australia and worldwide. Being overweight is a significant risk factor for these diseases. In fact, a report published in 2012 based on data gathered by almost 500 scientists from 50 different countries identified being overweight as the biggest health burden worldwide. Being overweight is responsible for the loss of more years of healthy life due to illness or early death than any other factor. It has overtaken lack of nutrition as a health burden. Scientific studies can provide data that health professionals can use to provide advice about diet and nutrition.

Smoking and alcohol are also risk factors for a number of the biggest killers. In Australia smoking rates have been decreasing steadily, largely as a result of health campaigns, education and new laws relating to tobacco advertising and the sale of tobacco products. In other parts of the world rates of smoking are much higher. Smoking increases the risk of cardiovascular disease and a range of other diseases including lung cancer. Some of the earlier studies pointing to a link between smoking and lung cancer focused on finding patterns in data. It was noticed for example that most people who developed lung cancer were smokers and those that smoked more cigarettes per day had a higher risk of developing the disease. Alcohol consumption, like smoking, increases the risk of cardiovascular diseases as well as cirrhosis of the liver and some cancers including breast, oral, liver and colorectal cancer. Alcohol is also implicated in a significant proportion of road accidents and other accidental deaths.

2.3.2 Health benefits of Mediterranean diet

A study led by Antonia Trichopoulou has shown that eating the type of food traditionally eaten by the people of Greece, Italy, Spain and Morocco (the Mediterranean diet) can help you live longer and reduce the risk of coronary heart disease and cancer. In these regions the main dish often consists of vegetables cooked in olive oil rather than meat. The Mediterranean diet also includes a lot of fruit, vegetables, fish and cereal. The study involved 22 000 Greeks. Each person was given a score based on their intake of foods typical of the Mediterranean diet. The researchers kept track of the participants' health for four years. Fewer of the participants who had higher scores (i.e. those who ate a diet that included a regular intake of the elements of the Mediterranean diet) developed cancer or died over the course of the study than those who had lower scores. There did not seem to be any one specific ingredient that contributed to the lower risk of cancer and death; it appears that the complete Mediterranean diet provides the most benefits.

On a more positive note, a behaviour that decreases the risk of disease is regular exercise. It reduces the risk of cardiovascular disease, type 2 diabetes, colon and breast cancer and osteoporosis. It also has other benefits for mental and physical health. Currently the National Physical Activity Guidelines for Australians recommend that Australians should aim to exercise at a moderate level (e.g: brisk walking) for at least 30 minutes on most days of the week and additional vigorous exercise to build up fitness and get extra health benefits. The guidelines recommend teenagers aim for an hour of moderate to vigorous activity every day, and up to 3 hours to benefit even more. So if you have a 20-minute walk to school each day, 30 minutes in PE class and 10 minutes working out at home, then

The Mediterranean diet

Regular exercise reduces the risk of a range of diseases, including cardiovascular disease.

play soccer on Saturdays and do an intense training session on Wednesdays you are meeting the guidelines for regular exercise, although additional training could further improve your performance at sport. On the other hand, if you are driven everywhere and you spend PE lessons complaining about having to exercise rather than building up a sweat, it might be time to get moving. Getting sufficient physical activity is a challenge for many adults, particularly those who have a job that involves sitting all day, and some workplaces are getting quite creative with ways of getting workers moving (see How about that!).

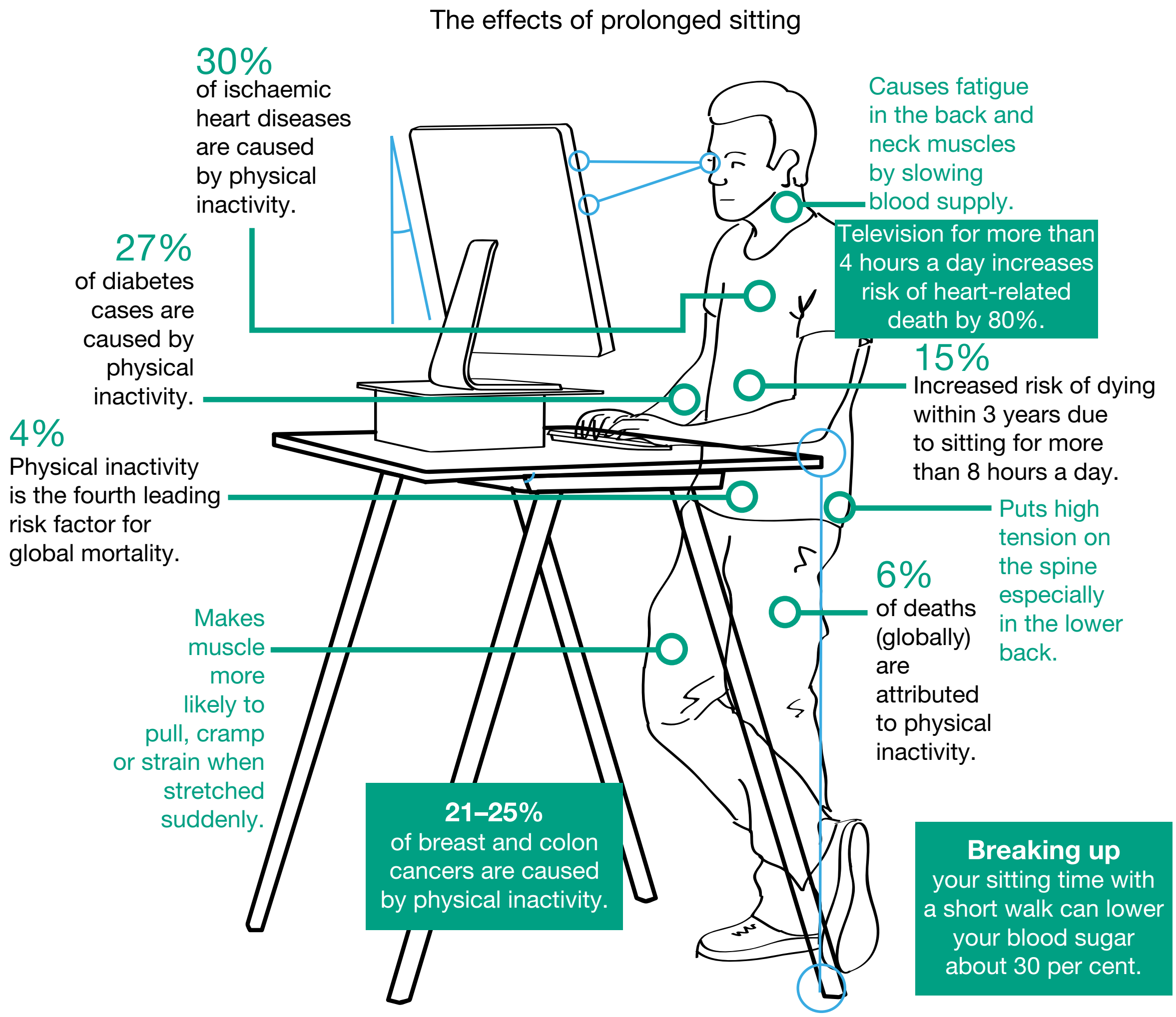
HOW ABOUT THAT!

Sitting is a dangerous activity

A study carried out by researchers at the University of Sydney and the Australian National University found that workers who sit for 11 hours or more a day are 40% more likely to die within 3 years than workers who sit for less than 4 hours a day. Sitting between 8 to 11 hours a day increases the risk of death within the next 3 years by 15%. With statistics such as these in mind, some workplaces have been designed to avoid having workers sit for long periods of time.

Instead of providing each employee with a desk, the workers move to different areas depending on the task they are working on and use wireless laptops or tablets to avoid being tied to a desk. While there is some traditional furniture designed for sitting there are also desks designed for standing and some meetings are held in open spaces with participants standing rather than sitting. This has the added advantage that it keeps meetings brief and focused.

The effects of prolonged sitting



2.3.3 Health for all Australians

In Australian cities most people have good access to doctors and hospitals. Bacterial infections are easily treated with antibiotics and most people have enough to eat. Not everyone chooses to have a healthy diet but the ingredients to prepare healthy meals are readily available in shops. The situation is unfortunately not the same in all parts of Australia. In the country people may have to travel great distances to visit a doctor and country hospitals sometimes find it hard to fill positions and may not get access to the latest equipment. A visit to a specialist can require an expensive trip to a city hospital for country patients.

In remote Aboriginal communities the situation is even bleaker. In fact, health standards are so poor in some Aboriginal communities that they compare with those of Europeans prior to the discovery of antibiotics. Access to medical services, particularly specialist doctors, can be difficult. Social issues also mean that in some Indigenous communities, lifestyle factors including smoking, high alcohol consumption and a diet low in fresh fruit and vegetables are contributing to poor health.

A challenge for the next generation of health professionals and policy makers will be to try to address this imbalance.

It is important to ensure that all Australians have access to health resources, including those living in remote Aboriginal communities.

2.3.4 Scientists trying to make a difference

Professor Ian Anderson and Associate Professor Jane Freemantle are two researchers collecting data that can help health professionals and politicians make wise decisions about Indigenous health issues.

Professor Ian Anderson is involved in a number of health organisations that deal with Aboriginal health issues. He grew up in the Koori community in Victoria but is a descendant from the Trawlwoolway Clan of North East Tasmania.

Associate Professor Jane Freemantle is a paediatric epidemiologist. That means that she collects and analyses data about the health of children. She has a special interest in the health of Aboriginal children.

Both researchers are currently involved in projects that gather data about the causes of death of Aboriginal and non-Aboriginal children. Collecting this data is important because it can be used to assess whether special programs and policies that are put into place to try to reduce preventable deaths in children are having any effect. Both researchers have been involved in numerous other research projects in the area of Indigenous health.

Professor Ian Anderson

Associate Professor Jane Freemantle

2.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What is meant by 'lifestyle factors' for diseases
2. List some lifestyle factors that increase the risk of cardiovascular disease.
3. Do you get sufficient exercise to meet the National Physical Activity Guidelines for Australians? **Explain.**

Skill builder

4. **Construct** a column graph to show the leading causes of deaths worldwide.
5. **Extract** the following information from the graph showing the main causes of death for Australians.
   (a) What is the leading cause of death for Australians?
   (b) What part of the body does the second highest cause of death involve (you may need to use a dictionary)?
   (c) What lifestyle factor contributes to the third and fourth leading causes of death in Australian men?
   (d) Which two types of cancers are the biggest killers of Australian women?
   (e) The number of deaths from lung cancer and breast cancer are similar, yet a lot more women contract breast cancer than lung cancer. Suggest a reason why.

(f) Which of the diseases listed are infectious diseases? Can you think of other infectious diseases that kill a small number of Australians each year?
(g) Why do you think that few Australians die from infectious diseases today?
(h) Why do you think that more women die from dementia and related disorders (*Hint:* think about the average lifespan for men and women)?

6. **Compare** the global and Australian leading causes of death.
   (a) List some infectious diseases that appear in the top 10 causes of death worldwide. Why do infectious diseases kill more people worldwide than Australia wide?
   (b) In Australia lung cancer is that fifth leading cause of death. How does this compare with the global data? How do you expect this to change over time? (*Hint:* Will there be more or fewer smokers in Australia in the future? Why?)
7. **Evaluate** the study on the effect of the Mediterranean diet on health by answering the following questions.
   (a) What feature of this experiment made it reliable?
   (b) The study relied on people describing their usual diet. Discuss the validity of this approach.
   (c) Another way of investigating the effect of diet would be to get half the participants to follow a particular diet and the other half to follow a different diet, then track their health over time. What are some ethical implications of studying the effect of diet in this way?
8. Use Excel to **construct** a column graph for the data in the table. Choose your headings and labels carefully. If you do not have access to a computer, draw the column graphs by hand on graph paper.

Think

9. **Explain** why it is important to collect accurate data about the health of Indigenous Australians.
10. Professor Ian Anderson grew up in a Koori community. Suggest why this might make him particularly suited to carry out research about Indigenous health and be involved in setting up policies to address some of the health issues affecting Indigenous Australians.

Discuss

11. There was a time when cigarettes were advertised on television, in magazines and in newspapers, anyone could buy cigarettes and it was common for people to smoke at work and in public places such as shopping centres and hospitals. In Australia it is now illegal to smoke in many places, children cannot purchase cigarettes, advertising of tobacco products has been banned, cigarettes are packaged in plain packages with large graphic health warnings and people are being educated about the health risks of smoking through public health campaigns and programs run in schools. Cigarette prices have also risen as a result of taxes on the sale of tobacco products.
    (a) **Evaluate** which of the above measures would be most likely to reduce the number of people taking up smoking.
    (b) **Assess** which strategy would be most likely to motivate existing smokers to quit.
    (c) Suggest other measures that could be put into place to reduce the number of people who take up smoking.
    (d) What strategies exist in Australia to reduce alcohol consumption? What else could be done?
12. Debate one of the following topics.
    (a) The legal drinking age should be raised to 21 in Australia.
    (b) Adults who supply alcohol to teenagers younger than 18 should be fined, even if the teenagers are their own children or their children's friends.
    (c) Schools and workplaces must take more responsibility for the health of their employees/students and provide healthy meals and mandatory exercise sessions.
    (d) Ultimately it is up to individuals to make healthy lifestyle choices. Governments and organisations have little to do with these choices.

Investigate

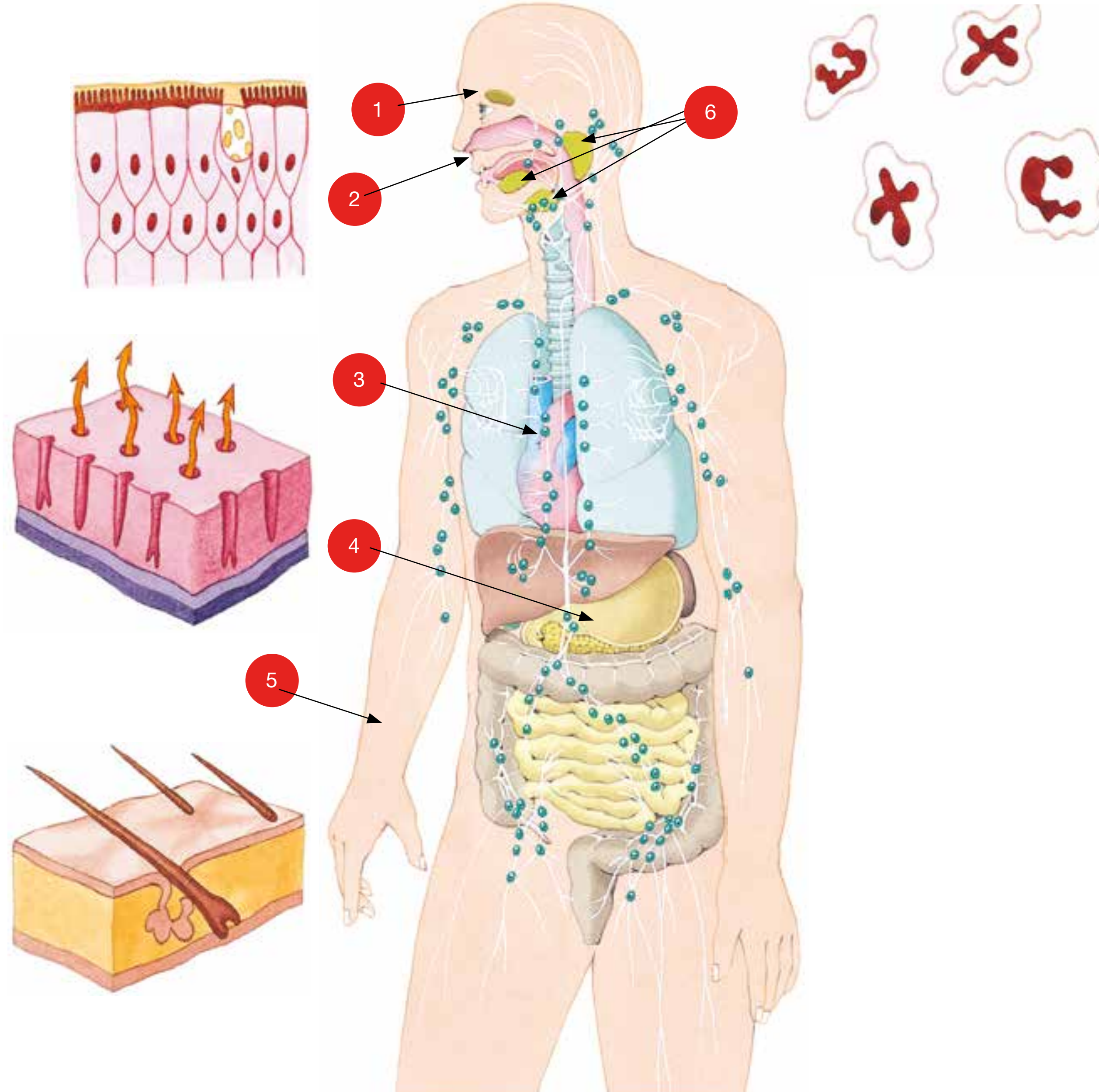
13. Research one the cardiovascular diseases listed below and prepare a poster or PowerPoint that includes information about the cause, symptoms and treatment/management of the disease.
    (a) Stroke
    (b) Heart attack
    (c) Arteriosclerosis
14. Find out about the work of Fred Hollows in Aboriginal communities.

2.4 Putting up defences

2.4.1 Lines of defence

Microbes and other disease-causing organisms are everywhere. It's a wonder we don't get sick all the time. Fortunately our bodies are quite good at fighting diseases.

The first line of defence involves preventing the entry of pathogens into the body.



1. **Lachrymal glands** near the eye produce tears to wash away dust, dirt, and foreign particles.
2. The **linings** of the body openings, like the nose and throat, produce a sticky **mucus** to help trap foreign particles.
3. The **lymph nodes** are lters or traps for foreign particles and contain white blood cells.
4. The **stomach** produces an acid that kills many microbes before they reach the intestines.
5. The **skin** is a surface barrier to most diseases.
6. Saliva produced by the **salivary glands** in the mouth contains substances to help resist and remove microbes.

Pathogens or pathogenic agents can cause disease, preventing or stopping the body from working well. A healthy body helps you to defend yourself against infectious diseases by setting up natural barriers, or lines of defence. The first and second lines of defence are described as being *non-specific*. They fight the same way for all infections, regardless of whether they have encountered them before. The third line of defence is *specific*. It fights differently for different types of invaders and may react differently if it has been exposed to them before.

2.4.2 The first line of defence

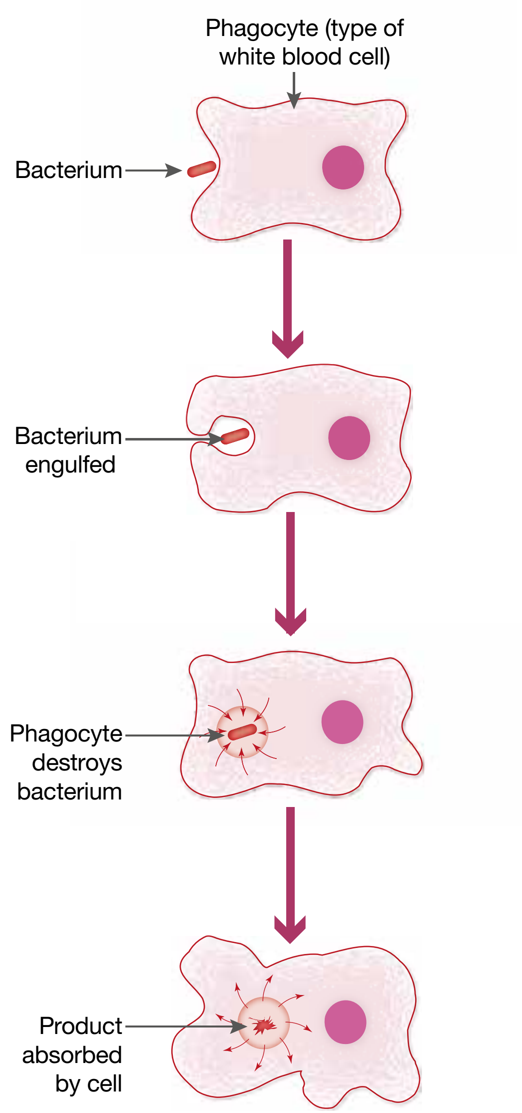
Your body's first line of defence is designed to prevent the entry of invading pathogens. Some of these defences are **physical barriers** (such as skin, coughing, sneezing, cilia and nasal hairs) and others are **chemical barriers** (body fluids such as saliva, tears, stomach acid and acidic vaginal mucus).

The skin is very effective at keeping out germs. It is waterproof and, unless you have a cut, microbes cannot pass through it. It is dry and slightly acidic; this prevents the growth of many bacteria and fungi on the skin. If your skin does become cut, the hole is very quickly patched up. A blood clot forms to seal the cut, then a scab forms and eventually the skin heals.

The parts of the body not covered by skin, including the inside of the mouth, nose, throat and vagina are covered with mucous membranes. As the name indicates, these surfaces produce mucus in which microbes become trapped. In the respiratory system there are also small hairs called cilia that beat and sweep the mucus out of the body. Another way to get the mucus out of the lungs is by coughing. This brings the mucus up to the mouth where it is swallowed.

The food we eat contains many microbes. A large number of these are killed by the hydrochloric acid in our stomach. Unfortunately the acid does not kill all microbes, so you can get very sick from eating food ridden with pathogens. Food such as undercooked meat can contain very harmful bacteria.

Phagocytosis



2.4.3 The second line of defence

Some pathogens manage to get past the first line of defence and enter the body. This is where the second line of defence steps into action. Have you ever had a cut that became infected, or an ear infection? The affected area becomes red, warm and swollen. This is a sign of inflammation, which is part of the second line of defence. Blood flow to the affected area is increased and the blood vessels become more permeable (they become more 'leaky'). White blood cells are sent to the area and they move out of the blood vessels to the site of infection. Some of these white blood cells are phagocytes. Phagocytes are white blood cells that can engulf and destroy pathogens.

Fever is also part of the second line of defence. Normal body temperature is about 37 °C. A temperature over 37.8 °C is considered to be a fever and indicates an infection. A fever can help your body fight an infection; in cases of a mild fever doctors may sometimes recommend that you just wear light clothing, rest, drink plenty of water and monitor the fever. If the fever rises to a very high temperature or lasts a long time it can be dangerous, particularly in young children, and paracetamol or ibuprofen may be recommended.

INVESTIGATION 2.1

Keeping germs at bay

AIM: To determine if hand washing and antibacterial sprays are effective in removing bacteria from commonly used surfaces.

You will need:

5 plates of nutrient agar
overhead projector pen
sticky tape
soap
ethanol
3 types of antibacterial soaps or antibacterial sprays
sterile cotton buds
incubator

Method

- Use the pen to draw a line down the middle of each plate of nutrient agar (on the outside of the part of the dish that contains the agar).
- Gently press your fingers over one half of the agar (you should not leave a mark on the agar).
- Wash your hands with the soap. Gently press your fingers over the other half of the plate.
- Seal the plate with sticky tape and label it with the pen.
- Repeat the above procedure with any available antibacterial soaps. You will need to use a different student's hands.
- Swipe a cotton bud over your desk, and then gently rub it over the surface of one half of an agar plate.
- Spray your desk with ethanol and dry it with a paper towel. Swipe a clean cotton bud over the desk and rub it on the other half of the plate.
- Repeat the above steps using any of the antiseptic sprays available (you will need to use a different surface than your desk).
- Incubate the plates upside down at 30 °C for 48 hours.
- Do not open the plates to look at them; look through the plastic.

Discussion

1. Explain why it is dangerous to open the plates after incubation.
2. After incubation you may be able to see colonies of bacteria or fungi on the agar. Each colony grew from one bacteria or fungus. Copy and complete the table below.

Substance used for cleaning	Number of colonies on half where hands/surface had been cleaned (*)	Number of colonies on half where hands/ surface had not been cleaned (*)

* If there are too many colonies to count, estimate what percentage of that half of the plate is covered with colonies.

3. Which cleaning substance was most effective at killing bacteria? Justify your answer.
4. Why were all the plates divided into two halves and the cleaning products used only for one half of each plate?
5. When biologists do experiments involving agar plates they usually include one plate of agar that is kept sealed and untouched. This plate is incubated with the others.
   (a) Why is this plate used?
   (b) If colonies of microbes were found on this plate after incubation, what would this indicate?
6. How does your school dispose of the agar plates safely?

2.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. (a) How many lines of defence are there?
   (b) **Describe** differences between these lines of defence.
2. **Distinguish** between physical and chemical barriers in the first line of defence.
3. **Explain** why many bacteria and fungi cannot grow on the skin.
4. **Explain** how mucous membranes and cilia work together to keep microbes out of the respiratory system.
5. **Outline** the role of the acid in the stomach in keeping us healthy.
6. **Define** the following terms: phagocytosis, fever, inflammation, antibacterial.
7. **Explain** why your finger may become red and swollen if you had a cut that had become infected.

Think

8. Design an experiment to test whether toothpaste can prevent the growth of bacteria.

Investigate

9. There is concern that overuse of antibacterial soaps and cleaning products may lead to bacteria becoming resistant to these products. Find out more about this.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Phagocytosis

2.5 Immunity

2.5.1 Lymphocytes

Some pathogens are able to successfully negotiate both the first and second line of defence. They are then faced with a third obstacle: an immune response involving a special type of white blood cell called a **lymphocyte**.

An **antigen** is any foreign particle that stimulates an immune response, including parts of bacteria, viruses and other pathogens. When an antigen enters the body, lymphocytes start to divide. There are two main types of lymphocytes: B lymphocytes and T lymphocytes.

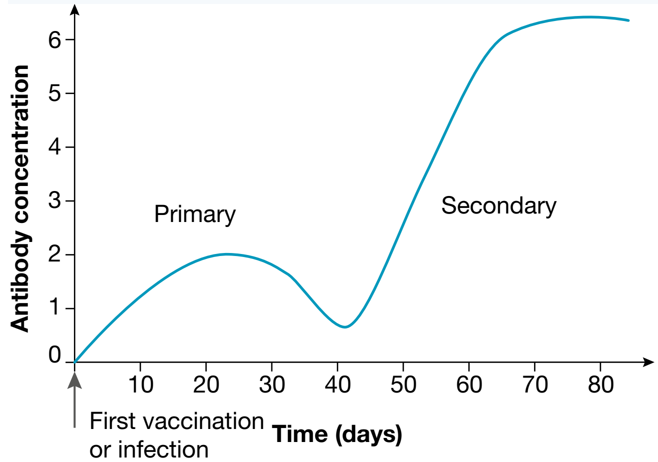
When B lymphocytes divide, plasma cells are produced. Plasma cells produce antibodies, which are proteins that bind with particular antigens. Some antibodies make the antigens clump together so they can be more easily engulfed by the phagocytes, while other antibodies act on antigens in different ways. For example, they might just render the antigen harmless without destroying it. Each type of antibody is highly specific; that is, it can work against only one particular type of antigen. The first time your body is exposed to an antigen it takes about 10–17 days for the correct type of antibodies to be produced at peak levels. Unfortunately, in some cases the patient will die before the immune system has had a chance to fight the pathogen.

T lymphocytes are not involved directly in the production of antibodies. There are different types of T lymphocytes; some produce substances that can attack pathogens, others secrete substances that attract or activate phagocytes, while others still assist the B lymphocytes in the production of antibodies.

2.5.2 Whatever doesn't kill you makes you stronger

If you had chickenpox, measles or mumps as a child, there is a good chance that you will not suffer from these ailments later in life, even if you have not been vaccinated against these diseases. In the previous subtopic we saw that when an antigen enters the body it causes certain types of lymphocytes to divide. Some of the cells produced are memory B and T cells. A number of these cells remain in the bloodstream for many years after the patient has recovered from the disease. If the person is exposed to the same antigen at a later stage, the memory B and T cells will recognise it and the correct type of antibodies will be produced at peak level within 2–7 days. Higher levels of antibodies will also be produced. In fact, the person may not even realise they have been exposed to the pathogen as the immune response will usually kick in before any symptoms develop.

On the second exposure to an antigen, the immune system is able to start producing antibodies more rapidly and in greater amounts.



2.5.3 Vaccination — fooling the immune system

Vaccination is a way of tricking the immune system into acting as though it has met a pathogen before. Edward Jenner took the first step towards developing a vaccine for smallpox when he noticed that milkmaids very rarely contracted smallpox. Before Jenner discovered vaccination, smallpox killed about a third of the people who caught it, and those that did recover from it were usually left disfigured. Milkmaids often contracted a milder form of the disease called cowpox, from the cows they milked; however, they did not contract smallpox. Jenner hypothesised that a cowpox infection provided some protection against smallpox. He set out to test his hypothesis and carried out an experiment on an 8-year-old orphan. Jenner collected some of the pus from a pustule on the hand of a milkmaid infected with cowpox, and then scraped some of the pus into the boy's arm. The boy developed symptoms of cowpox, and recovered. Forty-eight days later, using the same technique, Jenner infected the boy with smallpox. However, the boy did not contract smallpox; he was immune to the disease. When Jenner, a country doctor, presented his findings to the Royal Society in London, he was initially ridiculed and asked to provide more evidence. Over time his findings came to be accepted and his technique, which he called vaccination, became a standard medical procedure.

Smallpox pustules can be seen on this child's head.

Louis Pasteur was another immunisation pioneer. He grew cultures of bacteria and found that some old cultures of bacteria were too weak to cause disease when injected in chickens. If he injected fresh bacteria in the same chicken, they still did not get sick. Injection with the old, weakened bacteria had made the chicken immune to the fresh bacteria. He used this technique to develop a vaccine for rabies.

Vaccines have now been developed for numerous diseases including measles, rubella, chickenpox, polio and diphtheria. Some vaccines are made from a dead pathogen or a weakened version of the pathogen. Others are made from the coat of a virus that causes disease or some other part of a pathogen. Teams of scientists around the world are working towards developing new vaccines all the time.

2.5.4 Australian scientists leading the way in immunology research

Frank Macfarlane Burnet (1899–1985) was one of Australia's most acclaimed scientists. He was knighted in 1951 and received his Nobel Prize in 1960. In 1961 he was named Australian of the Year, and four years later Burnet was elected President of the Australian Academy of Science. He studied at the University of

Melbourne and started his career in Melbourne, then worked in England for many years, returning to Australia in 1944 to become director of the Walter and Eliza Hall Institute WEHI.

Burnet spent most of his career studying viruses. His doctorate thesis was on the phage, a type of virus that infects and kills bacteria. Scientists of the time thought there was only one species of phage. Burnet showed that there are, in fact, several species.

In 1928, there was public hysteria against vaccination after 12 children died after receiving their diphtheria injections. Burnet was part of a team that investigated this tragedy. His experiments showed that contamination of the vaccine caused the deaths, rather than the vaccine itself. This no doubt saved many further lives as people regained their confidence in vaccination.

Frank Macfarlane Burnet demonstrates his method of growing viruses by injecting them into eggs to a class of American postgraduate students.

2.5.5 Influenza strains

While in England, Burnet worked on the human influenza (flu) virus and developed a successful method of growing high concentrations of the virus using fertilised chickens' eggs. This work led to the development of an influenza vaccine. Burnet determined that there were several different strains of influenza. This meant a new vaccine had to be developed each year once the particular strain of influenza had been identified. His work laid the foundation for the discovery by Dr Peter Colman from CSIRO that all influenza viruses had a common part. Researchers then focused on ways to attack this common part and they were able to produce a new drug that is effective against all strains of influenza virus.

Burnet was so dedicated to his work that he was willing to risk his life to show others what he knew. In the early 1950s, CSIRO released the myxomatosis virus so it would infect and reduce the rabbit population in Australia. At the same time, there was an outbreak of encephalitis that made hundreds of people sick. The public started to blame myxomatosis. Burnet knew how the myxoma virus worked and that it could not affect humans. He set up an experiment where he and two colleagues, Professor Frank Fenner and Dr Clunies Ross, injected themselves with live myxoma virus. When it was shown that their health was not affected, the panic died down.

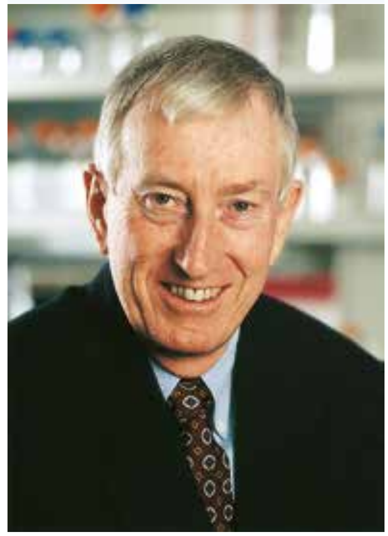
Burnet is best known for his Clonal Selection Theory which he published in 1957, around the same time that another immunologist called Jerne published similar ideas. Prior to publication it was thought that the immune system produced antibodies 'from scratch' in response to foreign substances. Jerne and Burnet proposed that we are actually born with lymphocytes capable of producing every single type of antibody we will ever need, but these lymphocytes start to replicate rapidly when an antigen locks onto them.

2.5.6 Matching body parts

Burnet's work inspired other scientists, contributing to our ability to perform transplants. He believed that the body learns about immunity at an early age. Burnet suggested that if you could put cells from another body into a fetus at the right time, the fetus would learn not to reject such cells later in life.

Dr Peter Medawar and his team of scientists used this idea when they injected donor tissue from a mouse into the embryo of another mouse. When the mouse was born, the team grafted skin from the donor mouse onto the newborn mouse. No rejection occurred. Now scientists know that they must match the **genes** carefully when they are looking for possible transplant organs. They use a close genetic match between recipients and donor organs, together with drugs that deaden the immune system, to perform successful transplantations. Today organs including heart, lung, kidney, cornea, bone marrow, skin and pancreas may be transplanted, extending the lives of many people. Immunology is still an important area of scientific research.

Professor Peter Doherty

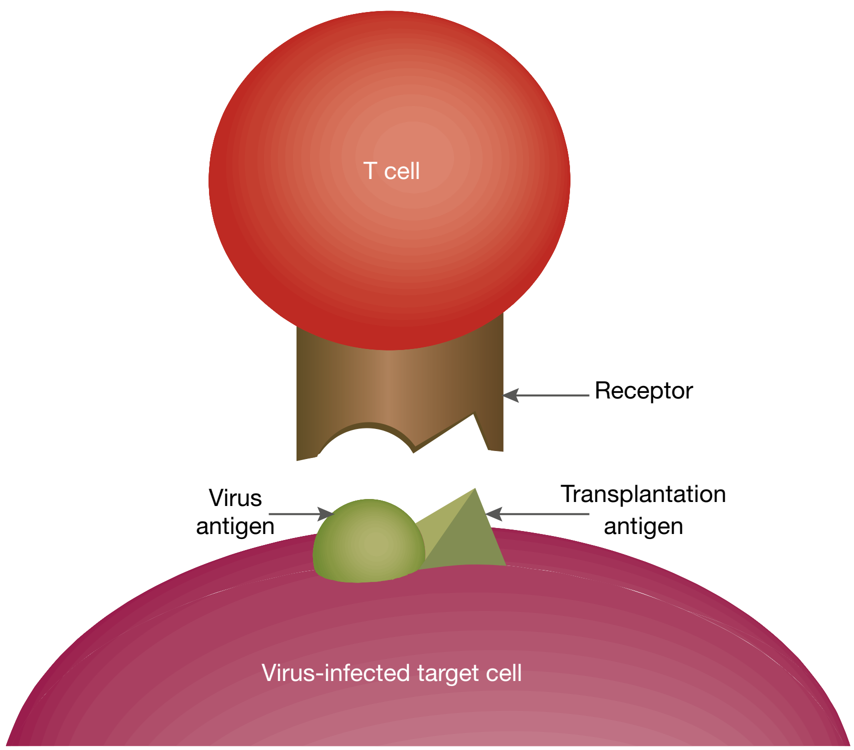


Professor Peter Doherty is another Australian immunologist who was awarded a Nobel Prize. He received a veterinary science degree from the University of Queensland and a graduate medical degree from the University of Edinburgh. He shared his Nobel Prize in 1996 with Rolf Zinkernagel when they described the way the immune system recognises virus-infected cells. In 1997 Peter Doherty was named Australian of the Year. Doherty and Zinkernagel worked at the John Curtin School of Medical Research in Canberra from 1973 to 1975.

The T lymphocytes (T cells) involved in the immune response have to be smart enough to avoid damaging their own organism. They need a recognition system so that they can identify the parts they must destroy and those they must protect. The body also needs to know when to activate the T cells.

Doherty and Zinkernagel studied mice to learn how their immune systems (particularly their T cells) protect them against the virus that causes meningitis. They discovered that mice can make killer T cells that protect them. However, when these T cells were placed in a test tube with infected cells from another mouse, they did not work. Doherty and Zinkernagel developed a model to explain why this happened. They said that each T cell carries a marker that allows it to recognise the cell of the organism it is protecting, as well as the antigen of the invading microbe. At the spot where the antigen attaches itself to the host, the T cell can make a matched fit and destroy the antigen. It works like two interlocking pieces of a jigsaw puzzle.

A killer T lymphocyte (T cell) must identify both the virus antigen and the cells of the organism it is trying to protect. It does this by making a matched fit at the place where the antigen is attached to the host. The host organism's transplantation antigen acts as the identifier.



2.5 Exercise: Remember and think

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Remember

1. Match the following words with their meanings.

Word	Meaning
(a) Antigen	(i) White blood cells that engulf foreign particles
(b) T lymphocytes	(ii) Only effective for one particular antigen
(c) Phagocytes	(iii) Cells that produce antibodies
(d) Antibodies	(iv) Any foreign particle that stimulates an immune response
(e) B lymphocytes	(v) Disease-causing organism
(f) Plasma cells	(vi) Proteins that bind with particular antigens and play a role in either destroying them or rendering them harmless
(g) Specific	(vii) White blood cells from which plasma cells are produced
(h) Pathogen	(viii) A type of lymphocyte not directly involved with the production of antibodies

2. **Recall** two Australian scientists who were awarded a Nobel prize for their work in the area of immunology. Outline two achievements of each scientist.
3. Why was the myxomatosis virus released by the CSIRO?
4. Is encephalitis linked to the myxomatosis virus? **Outline** how Burnet convinced people of this.

Think

5. **Construct** a flow chart showing the immune response. Your flow chart should make mention of antigens, B and T lymphocytes, and antibodies.
6. Jenner used an 8-year-old orphan to test whether infection with cowpox provided protection against smallpox. **Discuss** whether this was an ethical thing to do. Do you think such an experiment would be allowed today?
7. Pasteur's early immunisation experiments were carried out on chickens. **Assess** the advantages and disadvantages of using animals to test new medical procedures.
8. How did Burnet's findings about the influenza virus change the direction of research into flu vaccines?
9. Why is it important for T cells to recognise cells of the organism they are trying to protect?

Investigate

10. Use the **ASAP** weblink in the Resources tab to find out more about the important discoveries made by Sir Frank Macfarlane Burnet and Sir Howard Florey. Present your findings as a flow chart.

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Explore more with this weblink: ASAP

Complete this digital doc: Worksheet 2.3: Immunity (doc-12743)

2.6 Increasing immunisation rates

2.6.1 Immunisation

Many vaccinations are administered by injection.

Immunisation is a very effective way of preventing the spread of disease, yet many Australian children are not immunised against potentially deadly diseases for which vaccines are available. Should the decision to vaccinate a child be left up to the child's parents, or should it be compulsory for all children to be vaccinated?

Poliomyelitis (polio) is a disease caused by a virus. In some cases of polio the nerves are attacked by the virus and paralysis of the arms, lungs or diaphragm (which controls breathing) can result. Today we rarely hear about polio because it has become extremely rare as a result of vaccination programs. In your great grandparent's days it was common for people to have permanent disabilities as a result of having had polio in childhood. When the vaccine first became available parents rushed to have their children immunised. The polio vaccine is one of the many vaccines which are now available for all children at no cost to parents. Yet a small percentage of children are not immunised against polio. Immunisation is currently not mandatory in Australia. Should it be?

The table below shows the recommended vaccination schedule for Australian children.

Age	Vaccine
Birth	Hepatitis B (hepB)
2 months	• Hepatitis B, diphtheria, tetanus, acellular pertussis (whooping cough), *Haemophilus influenzae* type b, inactivated poliomyelitis (polio) (hepB-DTPa-Hib-IPV) • Pneumococcal conjugate (13vPCV) • Rotavirus
4 months	• Hepatitis B, diphtheria, tetanus, acellular pertussis (whooping cough), *Haemophilus influenzae* type b, inactivated poliomyelitis (polio) (hepB-DTPa-Hib-IPV) • Pneumococcal conjugate (13vPCV) • Rotavirus
6 months	• Hepatitis B, diphtheria, tetanus, acellular pertussis (whooping cough), *Haemophilus influenzae* type b, inactivated poliomyelitis (polio) (hepB-DTPa-Hib-IPV) • Pneumococcal conjugate (13vPCV) • Rotavirus
12 months	• *Haemophilus influenza type b (Hib)* • Meningococcal C (MenCCV) • Measles, mumps and rubella (MMR)
18 months	• Varicella (chickenpox)
4 years	• Diphtheria, tetanus, acellular pertussis (whooping cough) and inactivated poliomyelitis (polio) (DTPa-IPV) • Measles, mumps and rubella (MMR)

The vaccines listed in the table are paid for by the government. Many other vaccines are available; however, parents must pay for these. When deciding which vaccines the government will pay for, a number of factors need to be considered: how common the disease is, the effect of the disease, any possible side effect of the vaccine and the cost to taxpayers.

Some parents decide not to have their children immunised for the following reasons.

2.6.2 Religious reasons

Members of a religion called Christian Science generally prefer not to use vaccination and do not rely on medicine and surgery to treat disease. They believe that healing is achieved through prayer.

Jehovah's Witnesses are instructed not to accept blood transfusions. Up until the 1950s Jehovah's Witnesses were also instructed to refuse vaccination. This view has since been relaxed, as vaccines do not actually contain blood cells.

Particular vaccines have raised objections from other religions. There has been opposition to the polio vaccine from a small number of Islamic clerics in parts of Africa. Early methods for the preparation for the rubella vaccine raised concerns for the Catholic Church as it used to involve tissue from aborted fetuses. This is no longer the case. Some Christian groups have also voiced opposition to the HPV vaccine.

2.6.3 Safety concerns

This child in Pakistan is receiving polio vaccination drops during a World Health Day campaign to lessen the occurrence of the disease in countries where health care is not as easily available as in Australia.

While vaccines have saved many lives, there is the possibility of a negative reaction to a vaccine. This possibility is very small but it does exist. The majority of negative reactions are mild and may include a slight fever or pain at the site of the injection. In a very small number of cases a more severe reaction may occur. One in 100 people receiving the mumps vaccine may develop swelling of the salivary glands and 1 in 3 million may suffer from mild encephalitis (an infection of the brain). Overwhelmingly, the risk from the disease against which the vaccine offers protection far outweighs the risk from the actual immunisation. The combination of the measles, mumps and rubella vaccine, or MMR vaccine, raised particular safety concerns in the late 1990s, as small numbers of children appeared to develop symptoms of autism after receiving this vaccine. In 1998 a scientific paper raising concerns about the safety of the MMR vaccine was published. Since then the lead author of the paper has been accused of falsifying his results, and other charges of professional misconduct have been made against him. More importantly, numerous other studies have been carried out to investigate if there is a link between the MMR vaccine and autism. Children who have not received the MMR vaccine are just as likely to have autism as those who have not. It is now clear that the MMR vaccine does not cause autism. Unfortunately some parents remain doubtful about the safety of the vaccine.

2.6.4 Australian immunisation rates

In some countries vaccination is compulsory. In Australia parents have a choice, but many measures are in place to ensure that parents have their children immunised. For example, when parents apply for some family or childcare benefits they need to provide an immunisation history or a letter from a doctor stating that the parents have discussed vaccination with a doctor and chosen not to have their child vaccinated. When children start school or child-care an immunisation record or a letter from a doctor is usually required as part of the enrolment process.

2.6.5 Natural immunisation

Breast feeding gives babies the best start in life. A mother's milk contains the exact combination of nutrients a baby needs but it also contains something even more important: antibodies. Antibodies from the mother's blood can pass into the breast milk, providing the baby with immunity at a time when the baby's own immune system is still developing.

Breast milk contains antibodies which help protect babies from many diseases.

2.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Outline** two reasons why parents may choose not to have their children immunised.
2. **Explain** why breast fed babies may be less likely to get colds in the first few months of their life than bottle fed babies.

Think

3. **Discuss** whether immunisation should be compulsory in Australia.
4. **Discuss** whether parents or tax payers should pay for vaccines.

Analyse

5. **Calculate** the percentage of 24–27 months old who were not vaccinated against polio in 2012.
6. **Identify** the disease against which the least number of children were immunised in 2012. Suggest a reason.
7. Even if immunisation were compulsory there will always be individuals in a population that are not vaccinated. This could include young babies that have not yet reached the vaccination age, as well as individuals who cannot be vaccinated for health reasons (for example, children undergoing cancer treatment). As long as immunisation rates are high these individuals are not at risk. This is called herd immunity.
   (a) **Explain** why an infectious disease cannot spread through a population when immunisation rates are high.
   (b) In some parts of New South Wales immunisation rates have been dropping. There is concern that immunisation rates may fall below the levels required for herd immunity. Why should we be concerned about this?

2012 Australian immunisation rates

Vaccine	Per cent of 24–27 months old immunised
Diphtheria/tetanus	94.5
Polio	94.5
HIB	94.7
Hep B	94.0
MMR	93.7

Investigate

8. Research one of the diseases listed in the immunisation rates list above.
9. Find a newspaper or journal article about the HPV vaccine. **Summarise** the key points in the article.Breast milk contains antibodies which help protect babies from many diseases.

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Complete this digital doc: Worksheet 2.4: Vaccination (doc-12744)

2.7 Epidemic alert

2.7.1 Emerging diseases

How do scientists decide which problems to investigate? While curiosity about the world around us undoubtedly plays a part, often scientific research aims to address a need in society, such as the emergence of a new disease, or a plant or animal disease spreading through a population.

The SARS virus is a very nasty flu-like virus which hit the headlines in 2003. It causes fever, headache and difficulty in breathing. SARS stands for severe acute respiratory syndrome. The first victim of the virus was a 48-year-old businessman who had travelled from the Guangdong Province in China, through Hong Kong, to Vietnam. The businessman died of the disease and so did the doctor, Dr Carlo Urbani, who diagnosed the virus as a new one. The virus spread rapidly and, within weeks, had infected thousands of people around the world. To try to reduce the spread of the virus, schools were closed throughout Hong Kong and Singapore.

This photo was taken at Beijing airport in April 2003. The travellers are filling out health declaration forms. All travellers also had their temperature checked on arrival at the airport.

When new diseases such as SARS emerge it is common for teams of scientists to be mobilised to begin to investigate the new disease. Finding out as much as possible about the disease early on is critical. Often the first step for infectious diseases is to identify the pathogen and its method of transmission. This knowledge can be used to control the spread of the disease. Researchers may also begin to investigate possible treatments and vaccines for the disease.

In the case of SARS, scientists around the world worked frantically to find out how the virus was spreading. Once the virus responsible for SARS had been identified, Chinese researchers did experiments that showed the virus could live for five days outside the body in a drop of saliva. Another study showed the virus survived a stint of more than 24 hours on a plastic surface. German scientists found that household cleaners did not kill the virus, which meant that disinfecting hospitals with everyday cleaning fluids would not stop the virus spreading. In the end, the spread of the virus was stopped by isolating the people who had caught it and preventing them from having contact with other people. Fortunately, people with SARS showed flu-like symptoms very early on, which made it easy to spot victims, treat them and isolate them. If a virus takes a long time to produce symptoms, it is more difficult to prevent the virus from spreading.

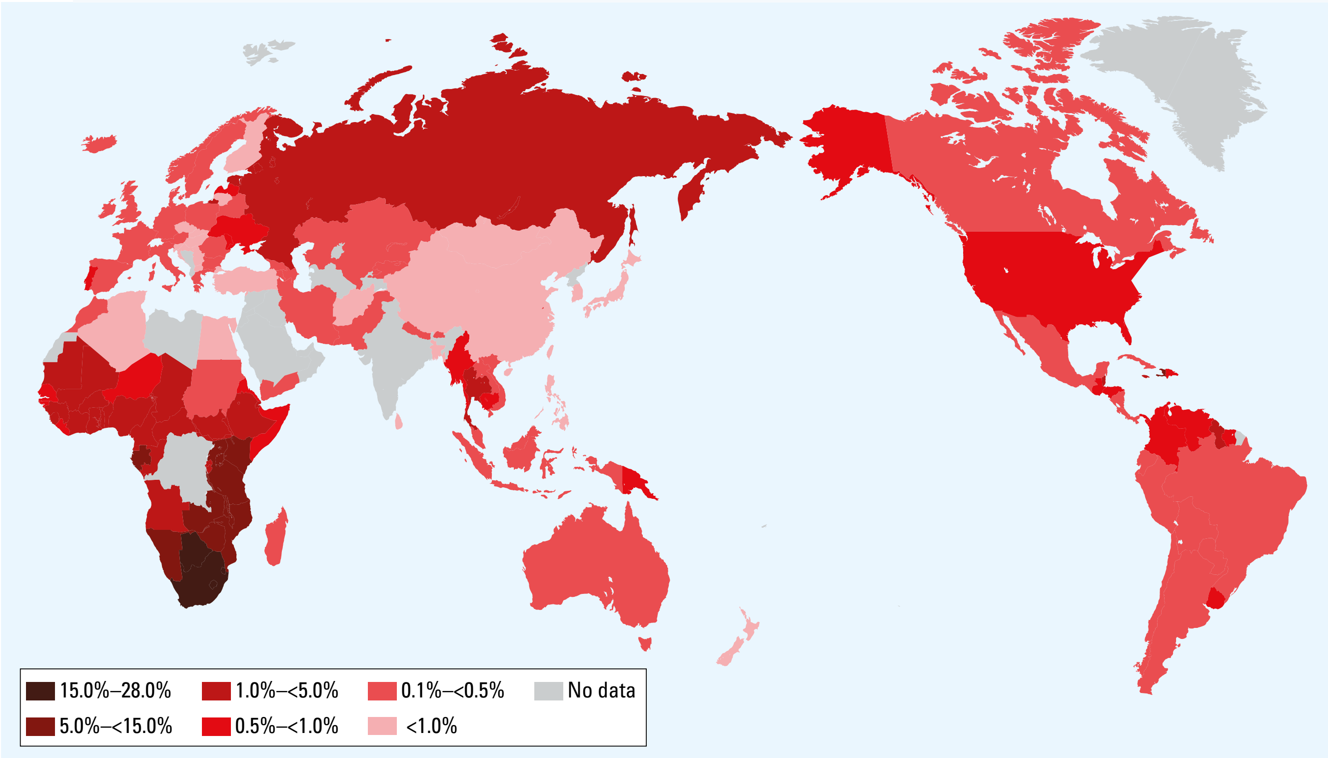
2.7.2 AIDS: a disease of the immune system

AIDS is also a relatively new disease. The first recognised cases of AIDS were reported in the United States in the early 1980s. At the time it was not known that a virus was responsible for the disease. Research about AIDS has been intense and we now know a lot more about it, although a cure or vaccine remains elusive. Unfortunately HIV has spread rapidly in the 30 or so years since the first cases were reported. In 2010 HIV was amongst the top 10 causes of death globally.

Currently the world is in the grips of an AIDS pandemic. An epidemic occurs when the incidence of a disease in a particular region is significantly higher than expected. If the epidemic spreads across a whole region such as a continent or the whole world it becomes a pandemic.

The map on the following page shows the percentage of adults living with HIV in various countries in 2011.

Percentage of adults living with HIV in 2011



2.7.3 AIDS — what do we know?

AIDS (acquired immune deficiency syndrome) is caused by a virus called **HIV** (human immunodeficiency virus). The virus infects a type of T lymphocytes called helper-T cells. When a person is first infected with HIV they might get flu-like symptoms for a short time, then have no symptoms at all for many years. During this time the body produces antibodies against the virus. These antibodies can be detected in blood. Someone who is HIV positive has antibodies for HIV in their blood. The virus destroys the helper-T cells and thus gradually damages the immune system. When the number of helper-T cells becomes very low AIDS symptoms might develop. These include night sweats, diarrhoea and fever. People who have full-blown AIDS have a very weak immune system and will often die from diseases that a healthy immune system could normally fight off. Also, people who have AIDS are at particularly high risk of a type of pneumonia, and a type of skin cancer called Kaposi's sarcoma.

There are only a few ways that HIV can be passed from one person to another, so educating people about HIV and how to avoid catching it is, at present, the most effective way of preventing its spread. HIV is present in the body fluids of infected people. Body fluids include blood, semen, vaginal fluid and breast milk. Most people who are HIV positive became infected with HIV through unprotected sex or sharing needles. Babies of women infected with HIV have a high chance of being infected, although research has shown that in many cases infection occurs during birth rather than pregnancy.

There is currently no cure for HIV. Medication can slow the progress of the disease, but it is expensive and has unpleasant side effects.

2.7.4 Australian breakthroughs in AIDS research

A team of Queensland researchers led by Associate Professor Harrich has made an important discovery. They have found a protein that the HIV virus uses to replicate in human cells and modified this protein. The modified protein stops HIV from replicating. So far they have tested the effect of the modified protein on HIV using cell cultures. They hope to start animal trials soon. If these tests show positive results human trials will then be carried out.

It is hoped that the research will lead to the development of a gene therapy treatment. Gene therapy involves introducing genes that direct the production of particular proteins into the patient. There are various ways of introducing these genes into particular cells.

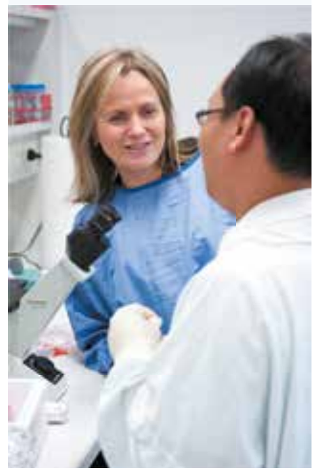
Associate Professor Harrich has been researching HIV for over 20 years. He started researching the virus early in his career at the University of California.

Professor Sharon Lewin is another Australian scientist working towards finding a cure for AIDS. Her team at Monash University is trying a different approach to the Queensland team. HIV can sometimes hide and lie dormant in some T cells. They are investigating a drug that can wake up HIV in these cells, so the virus can be detected by the immune system and destroyed.

Diseases do not need to make humans sick to cause serious concern. Some plant and animal diseases also cause serious alarm, particularly if they threaten an industry.

Associate Professor Harrich

Professor Sharon Lewin



2.7.5 Animal diseases

In August 2007 there was an outbreak of equine influenza in Australia. Equine influenza is a disease that affects horses and donkeys. There were fears that equine flu might impact on the horse racing industry, which is worth billions of dollars. Few horses die from equine flu but the horses are not able to race for the duration of the disease (usually about 2 weeks) and some time afterwards to ensure they make a full recovery. If equine flu had not been eradicated from Australia it is likely that some horse breeders may have thought twice before flying their horses to Australia for important races such as the Melbourne Cup.

Once the disease was detected in Australian horses a national response was launched. The CSIRO's Australian Animal Health Laboratory (AAHL) was involved because it is one of the few places in Australia with the necessary equipment to study this type of animal virus. The scientists at the AAHL identified the first case of equine influenza using tests that had been previously developed to detect bird flu. These tests were later used by veterinary laboratories in all states and territories to track the spread of the disease. CSIRO scientists also sequenced the genetic material of the outbreak virus. This helped identify

If equine influenza had continued to spread in Australia the horse racing industry could have been affected.

the most likely source of the infection and made it possible for vets to select the most appropriate vaccine for the virus. By March 2008 Australia was declared equine flu free.

2.7.6 Plant diseases

Plants can get sick too! You may have heard of the Irish potato famine of the mid nineteenth century. Potatoes were the staple food of the Irish. When potato crops were affected by potato blight, an infectious disease caused by the fungus *Phytophthora infestans*, a million Irish died of starvation and another million were forced to emigrate in search of food. Potato blight still destroys crops today. It has been estimated that worldwide the cost of crops lost to infection by this fungus adds up to about $6 billion a year.

Chemical sprays can be used to keep potato plants fungus free, but the fungus is evolving and the spray is becoming less effective at keeping it at bay. A development that may help society get the upper hand on *Phytophthora infestans* is the recent publication of the genome for the fungus. Scientists have sequenced the DNA of the fungus. It is hoped that this information may help develop more effective weapons against *Phytophthora infestans* or help scientists to breed more durable potato plants.

A potato infected with blight

2.7.7 Australian scientists working to beat a plant disease

Another plant disease caused by a fungal infection is rust. In Australia plants grown as food crops are bred to be rust resistant. However, over time new rust strains evolve. It is then necessary to develop new plant strains that are resistant to this new type of rust. It's a never-ending challenge. Peter Dodds and his team at the CSIRO are studying rust resistance in flax at the genetic level in the hope that the information can help develop plant strains that remain resistant to rust for a long time.

The two diseases described above are caused by fungal infections but there are also many bacterial and viral plant diseases. Some insects are also the cause of disease in plants.

Rust on a flax plant

INVESTIGATION 2.2

Plant diseases

AIM: To investigate some plant diseases

You will need:

samples of plants affected by disease, labelled with the name of the plant and the disease
digital camera or phone to take photos
dissection microscope or hand lens

Method

- Construct a table with the following headings: Name of plant, disease, photo, observations, additional information.
- Take photos of each plant sample and fill in the first 3 columns of the table.
- Observe each plant sample first with the naked eye, then using the dissection microscope or hand lens. Add your observations in column 4 of the table.

Discussion

1. Use resource material to locate information about the cause of the disease and how it affects the plant. Write this information in the last column of the table.

2.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** what the initials SARS stand for.
2. When were the first cases of AIDS reported in the US?
3. **Distinguish** between an epidemic and a pandemic.
4. **Identify** the regions of the world where the incidence of HIV infection is highest.
5. **Recall** which cells HIV attacks.
6. What are some symptoms of AIDS?
7. How is HIV transmitted?
8. **Outline** why animal and plant diseases can sometimes have very serious consequences for society.
9. **Outline** the role of the AAHL in the eradication of equine influenza from Australia.
10. **Identify** the cause of the Irish potato famine of the mid nineteenth century.
11. What is wheat rust?
12. Use the information in this section to **describe** an example of scientific research addressing a problem in society.

Think

13. **Explain** why it is important to determine how a virus is transmitted and how long it can survive outside its host.
14. **Explain** why it is easier to control the spread of a disease that has obvious symptoms shortly after infection.
15. Haemophilia is a blood clotting disorder. People who have haemophilia require frequent transfusions of factor VIII, a substance found in blood. Often a batch of factor VIII is produced from blood donated from a number of people. **Explain** how a number of haemophiliacs became infected with HIV in the 1980s. (Note: Donated blood is now screened for HIV to avoid the transmission of HIV from donated blood and blood products.)
16. Study the map Percentage of adults living with HIV in 2011 and extract the answers to the following questions from the map.
    (a) Which regions of the world have the highest incidence of HIV infection?
    (b) What is the rate of HIV infection for Australia?
17. In the 1980s and 1990s AIDS was often in the headlines because it was a new disease. Public health campaigns such as the grim reaper campaign also raised awareness of the disease and how it is transmitted. We hear a lot less about the disease now. Suggest why this could lead to an increase in the incidence of HIV infection in Australia.
18. **Explain** why the work of Peter Dodds and his team is important to Australian farmers and the economy.

2.8 Controlling fertility

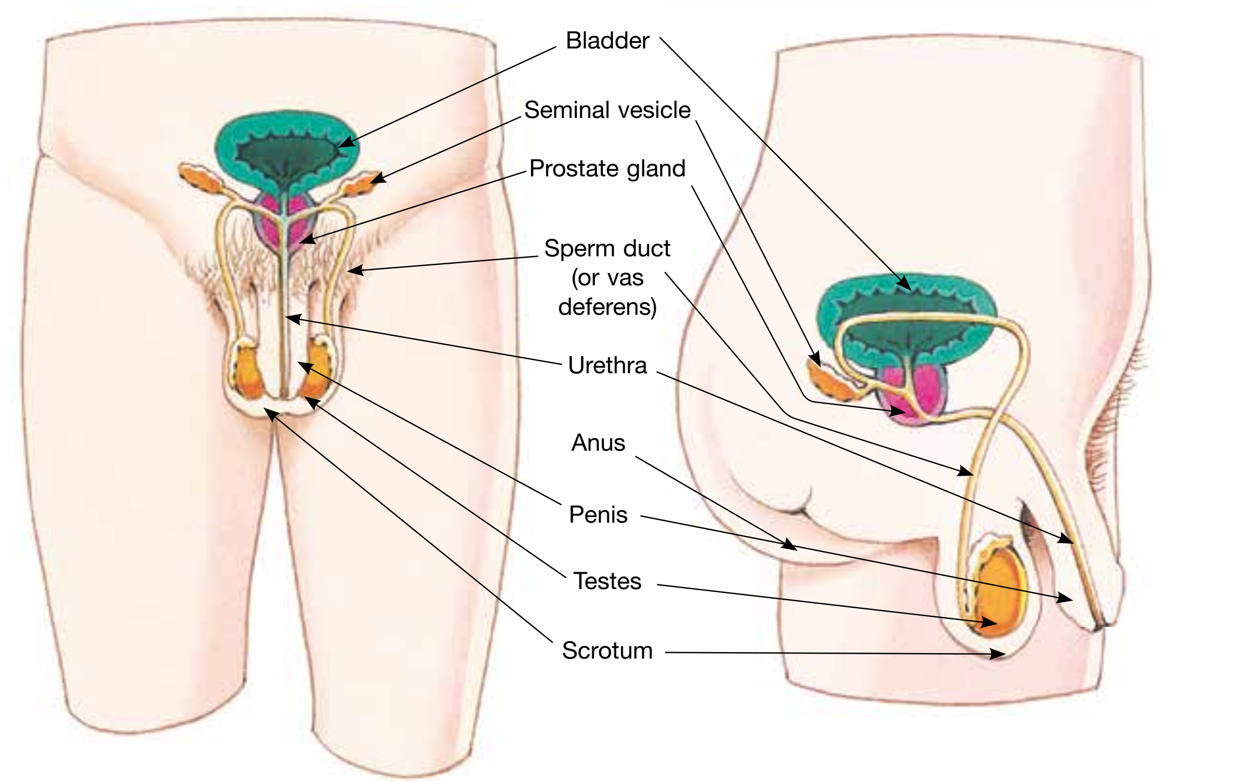
2.8.1 How babies are made

An area of medicine that has had a huge impact on health worldwide is the development of technology to control fertility through the use of contraception. This technology can delay the age at which women have their first child, space pregnancies and allow people to limit the size of their family.

To understand how fertility can be controlled we need to start by revising the male and female reproductive system.

In males the testes produce sperm cells. The testes hang outside the body in the scrotum. This keeps them a few degrees cooler than body temperature. This is essential for sperm production. The sperm cells travel away from the testes via a tube called the vas deferens. The prostate gland and the seminal vesicle produce substances that assist the sperm cell on their journey through the female reproductive system. By the time the sperm cells reach the urethra in the penis they are bathing in a fluid which, together with the sperm cells it contains, is called semen.

The male reproductive system

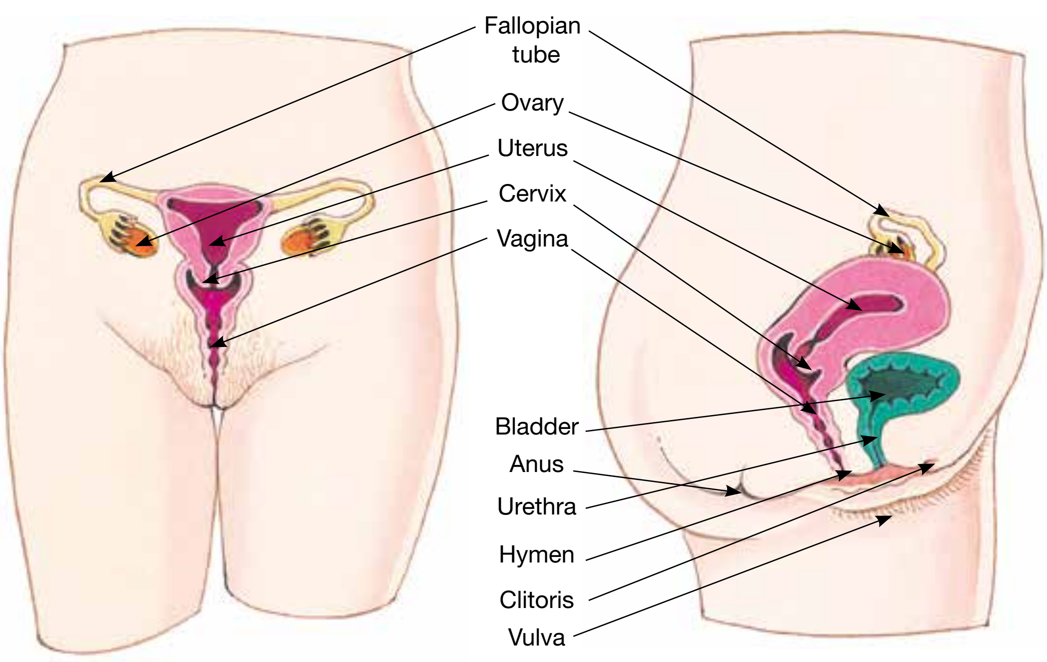


Parts of the male reproductive system

Part	Function
Testes	Produce sperm cells
Scrotum	Where the testes are located. Keeps the testes at a slightly lower temperature than body temperature.
Vas deferens	The tube through which sperm cells travel from the testes
Prostate gland	Secretes some of the liquid that is added to sperm cells to form semen. The fluid secreted by the prostate gland is alkaline and contains many chemicals including enzymes. It plays an important role in keeping sperm cells alive once they enter the female reproductive system.
Seminal vesicle	Also contributes some of the liquid that makes up semen. The fluid produced by the seminal vesicle contains proteins, enzymes, sugar, vitamin C and other substances. The sugar provides a source of energy for sperm cells.
Urethra	The tube inside the penis through which semen leaves the male's body
Penis	The penis swells during sexual arousal. Semen containing sperm cells is ejaculated (released) from the penis into the vagina.

Females produce ova (eggs) in their ovaries. On average one mature ovum from one of the ovaries is produced each month. Most of these eggs will not be fertilised. They will make their way to the uterus and be eventually expelled from the body during menstruation. Refer to subtopic 1.9 for further information about the menstrual cycle. During sexual intercourse semen is released from the penis. This is called ejaculation. The sperm cells travel through the cervix, into the uterus and eventually reach the fallopian tube where fertilisation might occur if an ovum is there. Only one sperm cell will get to fertilise the egg. The fertilised egg is called a zygote. After fertilisation it continues to move along the fallopian tube towards the uterus. The zygote divides into two cells, then four, eight and so on. After about 72 hours the zygote has reached the 16 cell stage. By day 4 the zygote enters the uterus. It now consists of a ball of cells called a morula. The morula continues to divide and implants itself in the lining of the uterus where it will develop into a baby over nine long months. Some of the cells of the morula develop into the placenta, a structure that allows the exchange of substances between the mother's and the baby's blood.

The female reproductive system



Parts of the female reproductive system

Part	Function
Ovaries	Produce ova. One egg is produced about once a month from one of the ovaries.
Fallopian tubes/oviducts	Tubes through which ova must travel to reach the uterus. Fertilisation occurs in the fallopian tubes.
Uterus	Where the baby grows and develops
Cervix	Lower part of the uterus connecting to the vagina. During childbirth the cervix needs to dilate (open up) to allow the baby to come out of the uterus.
Vagina	Semen enters the female's reproductive system via the vagina. When babies are born they are pushed out of the uterus and must pass through the vagina to enter the world.
Clitoris	Swells during sexual arousal and becomes highly sensitive when erect

2.8.2 Birth control

There are health risks to both the mother and the child associated with having children when very young (early to middle teens) and with having children that are born very close together, particularly in parts of the world where the standard of health care is lower than in Australia. There are other important reasons for people wanting to plan when and how many children they will have. Being a parent is a big responsibility and most people would prefer to wait until they are old enough to provide the best care for a child before becoming parents.

Birth control methods have been used with varying degrees of success for thousands of years. Today in wealthy countries such as Australia a wide range of contraception options is available, although there are groups in society who oppose some of these methods for religious or cultural reasons. In some developing countries there are also issues with access to contraception and cost.

2.8.3 Just say 'No'

Sexual abstinence (not having sex) is the only guaranteed way of avoiding unwanted pregnancy. It is also the most effective way to avoid contracting a sexually transmitted disease such as AIDS. It is possible for a person to be infected with a virus or bacteria that causes a sexually transmitted disease yet not show any symptoms. During sexual intercourse the disease causing organism can be transmitted from one partner to the other.

2.8.4 The protective condom

The only birth control device that provides some (but not guaranteed) protection against sexually transmitted disease as well as pregnancy is the condom. Condoms consist of a plastic sheath that fits over the penis. When the male ejaculates the semen is trapped inside the condom. Provided the condom is free of holes and used properly the semen does not enter the vagina. In Australia condoms are relatively cheap and readily available. A female version of the condom, called a femidon, which fits inside the vagina, is available in some countries. In some parts of the world where the incidence of HIV infection is high, AIDS prevention programs have included the distribution of free male and female condoms.

Some indication of the important role condoms can serve is suggested by the fact that Nepal holds an annual nationwide event called 'Condom Day'. The message for the people is that condoms will both assist in birth control and prevent transmission of serious diseases. The event is coordinated by the Nepal Red Cross Society, in conjunction with 70 of the country's government and other agencies.

A worker from The AIDS Support Organisation (TASO) in Uganda hands out free condoms to a couple.

The table below lists some contraception methods that have been around for decades or more.

Some birth control options

Method	How it works	Rating*	Factors influencing reliability as birth control method
Sexual abstinence  	Choosing not to have sexual intercourse	1+	None, as pregnancy cannot possibly occur
Coitus interruptus	Withdrawing penis from vagina before ejaculation	5	Loss of self-control; accidental transfer of sperm into vagina after withdrawal
Rhythm method(s)	Using the pattern of a woman's menstrual cycle, body temperature and/or vaginal mucus to avoid sexual intercourse when the woman is fertile	5	Loss of self-control; misreading or misinterpreting data or evidence
Condom 	A latex sheath is rolled down over erect penis before sexual intercourse. A tip at the top catches ejaculated semen.	3, or 2 if spermicide cream used	Condom puncturing, bursting during intercourse or slipping off; accidental transfer of sperm into vagina after intercourse
Diaphragm 	Small rubber dome is inserted into vagina in front of cervix to act as a barrier to sperm.	3, or 2 if spermicide cream used	Wrong size (doctor should determine); puncture; incorrect insertion or removed too soon (before six hours after intercourse)
Contraceptive pill  	Daily pill containing mix of synthetic hormones (oestrogen/progesterone) — either prevents ovulation, thins endometrium (womb lining) or increases mucus at entrance to cervix. Usually taken for 21 days, with seven-day break (when menstruation occurs).	1	Forgetting to take pill; bout of severe vomiting or diarrhoea; some antibiotics

(*Continued*)

Method	How it works	Rating*	Factors influencing reliability as birth control method
Intra-uterine device	Small plastic or metal object inserted in uterus by a doctor for extended period (e.g. years). May work by irritating uterus lining so implantation cannot occur. Some IUDs are made of copper (which kills sperm); others release hormones that thicken cervix mucus.	2	Virtually none, provided user has regular medical check-ups to ensure health of reproductive system
Vasectomy	Vas deferens are cut, permanently preventing sperm mixing with fluids produced by the prostate gland and the seminal vesicles.	1	Virtually none
Tubal ligation	Fallopian tubes are permanently blocked, cut or burnt so that ova cannot reach the uterus, and sperm cannot reach and fertilise them.	1	Virtually none

* Rating measures practical effectiveness for users, not effectiveness in principle (that is, if always used properly):
1 = extremely reliable, 2 = very reliable, 3 = mostly very reliable, 4 = generally fairly reliable, 5 = tends to be unreliable

2.8.5 Newer contraception methods

Because there is still no such thing as the perfect contraceptive, research in this area of medicine is continuing.

For women, some newer contraceptive methods include transdermal patches that stick onto the skin and release hormones, daily vaginal pills that dissolve into spermicide when inserted into the vagina before intercourse, and the Filshie clip, a type of fallopian tube clamp.

Products being investigated for men include hormone injections or implants to reduce sperm levels, male anti-fertility vaccines that regulate sperm and testosterone production, sperm duct plugs that inject liquid plastic into the vas deferens, chemical sterilisation, and gossypol, a chemical which reduces sperm production.

HOW ABOUT THAT!

Cutting off sperm cells' motor could lead to new contraceptive

Australian researchers have found a way to reduce sperm cells' ability to swim. This discovery could lead to the development of a male contraceptive pill. The research was led by Moira o'Bryan of Monash university. By deliberately inducing a mutation in a gene called RABL2 in mice, they found that this gene was necessary to allow sperm cells to swim. A drug that could temporarily inactivate this gene could thus control fertility in males.

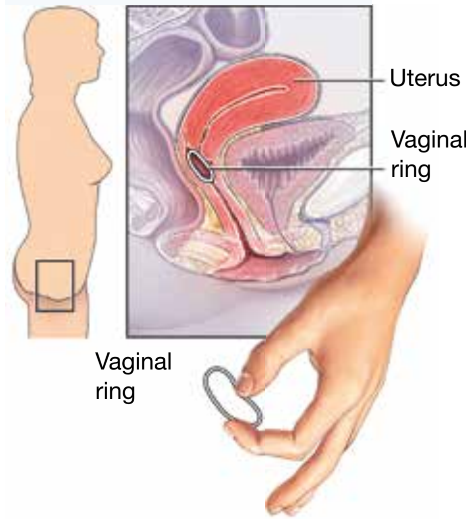
2.8.6 In for the long haul . . .

There are also a variety of long-acting contraceptive methods available. Once 'introduced', these require no further action by the user for a long time. A disadvantage of most of them is that they require medical intervention for insertion and removal.

Examples include:

- Depo injections: Also known as Depo-Provera, this is a hormone injected into the user's buttocks muscles that prevents ovulation for about three months.
- implants: A contraceptive implant (about the size of a matchstick) is inserted under the skin of the inner, upper arm. There are different types of implants. Depending on the type they can prevent ovulation for up to 3 or 5 years.
- hormone releasing intra-uterine devices (IUD): Minera is a T-shaped plastic device that acts directly on the lining of the uterus to make it thin and unreceptive to implantation of the fertilised egg. It also changes the fallopian tube lining, the mucus produced by the cervix, and can stop ovulation in some women. It provides continuous contraceptive protection for about five years.

This vaginal ring can function for up to three weeks secreting hormones similar to those in contraceptive pills.



2.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Write down the name of the organs that have the functions listed below.
   (a) Produce sperm cells
   (b) Produce ova
   (c) Tube leading from the testes to the urethra
   (d) Tube inside the penis through which urine and semen exit the penis.
   (e) Tube leading from ovary to uterus, where fertilisation occurs.
   (f) Where the baby grows and develops
   (g) Lower part of uterus that needs to dilate (open up) for the baby to be born.
2. What is the role of the placenta?
3. What is the only certain way of avoiding unwanted pregnancies and sexually transmitted disease?
4. Name two methods of birth control that work by providing a physical barrier to conception. **Explain** how each works.
5. **Describe** what an IUD is and how it works.
6. **Outline** an important function that condoms serve besides being a form of birth control.

Think

7. **Explain** why you think tubal ligation and vasectomy are so extremely reliable. Use diagrams in your explanation.
8. **Discuss** why birth control methods such as the rhythm method and coitus interruptus rely very heavily on personal self-control.
9. **Discuss** why birth control is such a deeply personal issue, about which people might have a range of differing opinions.
10. In 2006 politician Peter Costello famously encouraged Australians to have 'one [child] for mum, one [child] for dad and one for Australia'. Similarly when the Pope visited Australia in 2008 he encouraged people to have more babies. China on the other hand has a one child policy where, for most couples, severe financial penalties apply if they have more than one child. **Discuss** whether humans should be encouraged to have fewer or more children. In your answer provide at least:
    (a) one economic argument
    (b) one scientific argument.

Investigate

11. In small groups, complete a research project on one of the following topics. Presentation of your findings can be in the form of an illustrated report, PowerPoint display or annotated poster.
    (a) The risks posed by a number of sexually transmitted diseases (including AIDS) and the benefits gained by condom use
    (b) A new birth control method being investigated and/or developed, and how it would work, such as birth control pills for men, or birth control injections for women (to name only two)
    (c) How immunocontraception is being investigated as a means of controlling some feral animal populations. Give examples.
12. Use the **Reproduction** weblink in the Resources tab to work through the online activities relating to the function of the parts of the reproductive system.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Reproduction

2.9 Reproductive technology

Science as a human endeavour

2.9.1 Battling to breed

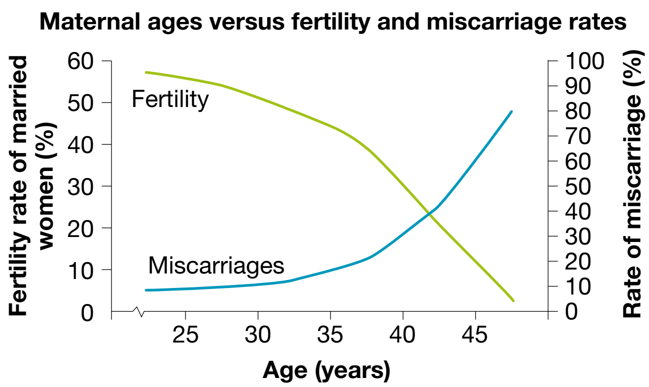
While many couples use contraception to avoid falling pregnant, some couples face the opposite problem; they find it difficult to fall pregnant. If a couple has been having regular unprotected sex for a year and they have not succeeded in conceiving a child, they are considered to be sub-fertile or infertile. For infertile couples, 40% of cases are due to a problem with the woman's reproductive system, in 40% of cases the male's reproductive system is not functioning properly, in 10% of cases both partners have a problem and in 10% of cases the cause cannot be determined.

Some of the reasons why couples may not be able to have children

Type of problem	Definition/reason
Gametes	Sperm or ova are not produced in sufficient quantity or quality.
Impotence	Some men cannot maintain an erection during sexual intercourse.
Blockage or damage	Some women may have blockages in their reproductive system (e.g. fallopian tubes), preventing fertilisation.
Repeated miscarriages	The pregnancy cannot be maintained. The baby may die inside the womb or be born before it is sufficiently developed to survive.

For women, fertility is strongly linked to age. Women usually reach menopause in their late forties to early fifties. After this time their periods stop and they no longer ovulate. Fertility starts to decline well before menopause though, and women in their forties are less fertile and have a greater chance of miscarriage than women in their twenties or thirties.

Fertility decreases as a woman becomes older.



2.9.2 Artificial insemination — a reproductive technology

Reproductive technologies are methods involving medical techniques or technology to enable a woman to become pregnant if she is not able to naturally.

One of these reproductive technologies is artificial insemination (AI). AI involves injection of sperm into the woman's uterus close to the time of ovulation. The sperm may be collected from her partner, or from another male if her partner is sterile. Artificial insemination has also been used in agriculture in the production of prime farm animals, and in the breeding programs for endangered species.

2.9.3 In-vitro fertilisation (IVF)

In IVF the egg and semen are combined outside the mother's body in a dish. In-vitro means 'in glass' because glass dishes were used when IVF was first carried out. Some people refer to children conceived using IVF as 'test-tube babies' but this term is not accurate either as the egg and sperm are usually placed in a shallow dish rather than a test tube.

When a couple undergoes IVF, the woman will usually have hormone injections to stimulate many eggs to ripen in her ovaries. Regular ultrasounds determine when the eggs are mature. A different hormone called LH is then administered to trigger ovulation and the eggs are harvested using a fine needle. The father must produce a semen sample which is then combined with the eggs that were collected. The eggs are monitored closely to check whether they become fertilised and to check whether they divide normally. If multiple embryos develop, the doctors must try to determine which ones have the best chance of survival. One, or sometimes two, embryos are then placed in the woman's uterus where they will hopefully implant. If more than two embryos form, some may be frozen. It is up to the parents to decide if their excess embryos will be frozen and what will happen to these embryos later on.

The first baby to be conceived using IVF, Louise Brown, was born in 1978; that's probably around the time that your parents were born. She was considered a miracle of science. Today about one in 33 babies born in Australia started their life in a dish. IVF clinics have been able to greatly improve their success rates by fine tuning the procedure they use. Other techniques have also been developed to assist couples with specific problems.

Louise Brown is now in her thirties and is a mother herself. Louise was conceived by IVF but she was able to fall pregnant naturally.

IN-VITRO FERTILISATION

Step 1 — A woman is given drugs to make her ovaries release a number of mature ova at one time.
Step 2 — These mature eggs (and surrounding fluid) are removed, using a fine needle. The microscopic lens of a laparoscope guides the medical specialist. Some eggs may be frozen, and stored in liquid nitrogen.
Step 3 — After being incubated (kept warm at a constant temperature) for a few hours, the eggs are mixed with sperm (fresh or thawed) in a glass dish. First, the outer protein layer is removed from sperm cells — this is what happens naturally in the female body.

In-vitro fertilisation

Needle penetrating the follicle containing the ovum and surrounding fluid

If the father has a very low sperm count or his sperm cannot swim, a single sperm can be injected directly into the egg. This is shown in the photo at right, on the previous page.

Step 4 — Any zygotes that form are allowed to divide. The embryo showing the best chance of survival is then placed in the woman's uterus using a catheter (fine, hollow tube). Surplus embryos may be frozen.

2.9.4 Donor egg and sperm

In cases where a man has a very low sperm count donor sperm can be used for artificial insemination or IVF. Sperm can be collected from donors and kept frozen until it is needed.

Women who cannot produce eggs may be able to use donor eggs. As hormone treatment and an invasive medical procedure are required to obtain the eggs, few women donate eggs. In Australia women cannot sell their eggs but in some countries they can. The use of donor eggs has allowed women to have children after menopause. For women who are nearing menopause and are still hoping to have children in the future a treatment on offer is egg freezing. The woman's own eggs are harvested and frozen. Egg freezing is also being offered to women about to undergo cancer treatment that may damage their eggs. Currently, the chance of producing a baby from a thawed egg is very low because, unlike sperm cells, egg cells are large and easily damaged by the freezing process.

Embryos can be donated as well. Sometimes couples who have succeeded in having a baby using IVF may donate any leftover embryos to be used by another couple who cannot have children.

2.9.5 The controversy

IVF is an example of technology on which there are many different opinions. For some it is considered to be wonderful technology because it allows couples to have the child they have wanted for so long. Others are concerned that it is going against nature. Religion may play a part in determining a person's attitude to reproductive technologies.

Some other issues that may affect a couple's decision to have IVF treatment include cost, the side effects of hormone injections, the time, inconvenience and discomfort that the treatment involves, as well as the psychological stress it causes, particularly if the couple has to have many attempts at IVF without success. IVF raises questions for the rest of society as well; for example:

- To what extent should IVF treatment be funded by taxpayers?
- Should there be a maximum age limit for IVF treatment?
- Should Australian women be able to receive payment for their donated eggs?

HOW ABOUT THAT!

Eggs in your arms?

More recent reproductive technology is investigating the storage (by freezing) of the ovary tissue itself (and the immature eggs it contains). Thawed strips of the tissue are later transplanted into the woman's pelvis or under the skin in her arm. The hope is that new blood vessels will grow and regenerate the tissue. If this happens, *hormones* will be produced that will mature the eggs, which can then be harvested. So far, some embryos have been produced this way, but no babies . . . yet.

2.9.6 Is the baby alright?

Until the last few decades women knew very little about their baby until it was born. Today many tests can be carried out during pregnancy to check whether the baby is healthy.

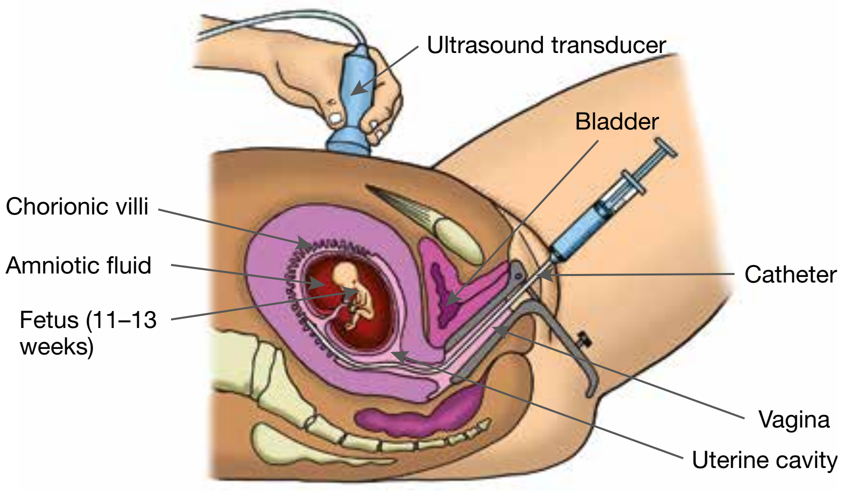
For couples using IVF, tests are available even before the embryo is transferred to the womb. When the embryo is just a bunch of cells, doctors can remove one cell and test it for certain genetic conditions. Only embryos that do not carry the genetic defect that was tested for will be transferred to the womb. Couples who have already given birth to children with a severe genetic defect or who have a family history of a particular hereditary disease may choose to use IVF for this reason alone.

It is now routine procedure for pregnant women to have an ultrasound around 12 weeks of pregnancy. This uses ultrasound waves to 'see' inside the womb and some birth defects can be detected at this stage. A measurement can be taken to find out how much fluid has accumulated under the skin at the back of the baby's neck during this ultrasound scan. Babies who have Down syndrome or certain other genetic problems usually accumulate more fluid than other babies. If the amount of fluid is high parents may choose to have further tests carried out such as CVS or amniocentesis. These tests provide information of the baby's genetic makeup.

In a CVS test a sample of the chorion, the lining of the uterus that develops into the placenta, is collected using a needle. The cells are analysed for certain genetic defects. This test is done between 11 to 13 weeks of pregnancy.

An ultrasound scan

A CVS test involves collecting a sample of the chorionic villi.



Amniocentesis is usually performed around 15–19 weeks of pregnancy. A sample of the liquid around the baby is collected using a needle, since this liquid contains cells from the baby. These cells can be tested to find out if the baby has Down syndrome. Some, but not all, genetic defects can be picked up by this test; however, there is a slightly increased chance of miscarriage after this test.

A more detailed ultrasound that can determine the sex of the baby is carried out around 18 weeks of pregnancy. Certain medical conditions are picked up during this routine ultrasound as well.

If any of the above tests pick up abnormalities in the baby, the parents are faced with difficult decisions. While some medical conditions detected during pregnancy are treatable, many are not. In Australia parents have the option of terminating a pregnancy (having an abortion) if major problems are picked up in any of the tests described above.

2.9 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Outline** the techniques that would help a couple reproduce if:
   (a) the male was infertile
   (b) the male's sperm cells were not able to swim
   (c) the female had blocked fallopian tubes
   (d) the female had a history of miscarriages.
2. **Distinguish** between:
   (a) artificial insemination and in-vitro fertilisation
   (b) ultrasound and amniocentesis.
3. **Outline**, in point form, the steps involved in IVF.
4. **Explain** why the term 'test-tube' baby is misleading

Think and discuss

5. Who should decide who is entitled to access reproductive technologies? **Discuss** this with your team and report back to the class.
6. **Explain** how a girl born using IVF technology can have a twin brother who is five years younger.
7. As a class, **discuss** the issues raised by the following scenarios.
   (a) Who owns stored embryos if the people who supplied the gametes die? Can they be 'inherited' or used by others? Should they be used for research (for example, to produce stem cells)? Should they be destroyed?
   (b) Should sperm or ova be harvested from people who have recently died for use by others?
   (c) Should commercial surrogacy be allowed? (This involves a woman who carries an embryo in her uterus created from the gametes of others for a fee.)
8. IVF is an expensive procedure. Couples having IVF treatment can claim some of their expenses from Medicare; however, this was not always the case. **Discuss** to what extent IVF treatment should be covered by Medicare. Should the rebate be available to all people (e.g. women past the age of menopause, single women etc.)? In your answer include:
   (a) an economic argument
   (b) an ethical argument
   (c) a scientific argument
   (d) a legal argument.
9. Prenatal testing is not compulsory in Australia.
   (a) **Discuss** whether prenatal testing should be compulsory.
   (b) **Discuss** whether parents should have the right to decide whether to terminate a pregnancy if a major birth defect is detected.
   (c) A couple found out that they were both carriers of the gene for Tay Sachs disease. That means that if they have a child there is a one in four chance the child will have Tay Sachs disease. Children who have Tay Sachs appear healthy at birth. As they get older the child gradually becomes blind, deaf and unable to swallow and loses muscle tone and mental capacity. Most children who have Tay Sachs die by the age of 4 or 5. Tay Sachs can be detected using CVS or amniocentesis. If IVF is used, it can also be detected in embryos before they are implanted. Imagine that you are a genetic counsellor. **Outline** some ways that the couple can minimise the chance of having a child that has Tay Sachs. Explain how the couple's religious beliefs could impact on their decision.

Investigate

10. Find out about Down syndrome. **Summarise** the information you find under the following headings: 'Cause', 'Symptoms' and 'Management'.
11. Find out whether the number of children born with Down syndrome is increasing or decreasing. **Predict** how it will change over the next 25 years. **Justify** your answer.
12. Use the **IVF** weblink in the Resources tab to watch an animation of in-vitro fertilisation.

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Explore more with this weblink: IVF

2.10 Reproduction in the news

Research in the area of reproductive technology has brought along rapid change. There is a big difference between what is scientifically possible and what is socially acceptable. The news snippets in this spread provide examples of situations where the use of reproductive technology has raised ethical, social, legal or economic issues. Each snippet is a summary of a news story that was either published in a newspaper or was presented on the news.

Some of the articles that follow are about surrogacy. Surrogacy is when a woman carries and delivers a baby for another couple. In some cases sperm from the father is used to artificially inseminate the surrogate mother. In other cases an embryo from the couple trying to have a child is produced by IVF and then transferred into the womb of the surrogate. In commercial surrogacy the surrogate is paid, sometimes large amounts of money, to carry the child. Altruistic surrogacy does not involve the exchange of money. A friend or family member might carry a child for a couple for example, and not expect payment in return. At the time of writing altruistic surrogacy was legal and commercial surrogacy using an Australian surrogate was illegal in all Australian states. In some states it was legal to use an overseas surrogate, although there were calls to change these laws in some states. Couples using overseas surrogacy may also face legal difficulties when bringing the child into Australia and being recognised as the child's parents under Australian laws.

2.10.1 Widow allowed to use husband's sperm

An Australian woman has been allowed to extract her dead husband's sperm so that it can be used for IVF treatment. The couple had been trying to fall pregnant and had been undergoing IVF treatment before the man's death. When the woman made the request she was told she needed a court order, however the judge who heard the case said that in future when a similar request is made senior doctors at the hospital should be able to grant the request so that there would be no need to go to court unless the death was suspicious.

Semen can be collected from a recently deceased man and frozen for later use, but is it ethical to do so?

2.10.2 Oldest mothers

Adriana Iliescu had IVF treatment using donor eggs. She started fertility treatment at the age of 58. At the age of 66 she finally succeeded in falling pregnant with twins. One of the twins died in the womb, the other baby was then delivered by caesarean section 6 weeks before the due date weighing 1.4 kg.

Mrs Iliescu's record was beaten by Rajo Devi Lohan, an Indian woman who gave birth at the age of 70. She died before her child reached the age of two as a result of complications from the IVF treatment.

Adriana Iliescu gave birth at age 66

2.10.3 India's baby farms

Indian clinics specialising in surrogacy are offering rich couples from around the world the opportunity to use a poorer Indian woman as a surrogate. The women are paid to act as surrogates. They live together while they are pregnant and they receive regular health checks and have all their meals prepared. For American couples (another country where commercial surrogacy is legal) the cost of an Indian surrogate is much less than an American surrogate.

2.10.4 Mothers for hire

For Vaghela, becoming a surrogate for an American couple was a way of providing her two children with an education and a chance for a better life. Unfortunately towards the end of the pregnancy she developed complications and died. The baby was delivered by caesarean section. It was premature but survived. Even if her family could afford a lawyer, they would not be able to sue the doctors or the American couple because Vaghela signed a contract exempting them from all liabilities. The contract also says that in a situation where the mother became very sick in late pregnancy and at risk of dying she is to be 'sustained with life-support equipment to protect the foetus' viability and ensure a healthy birth on the genetic parents' behalf'.

Mrs Vaghela's family have been given 1 million Indian rupees (the equivalent of $17 600 Australian dollars) by the American couple as compensation.

Source: *Sydney Morning Herald*, 7 September 2012.

2.10.5 Designer babies

Professor Julian Savulescu, an ethicist from Oxford University, argues that parents should be able to use genetic testing combined with IVF to choose the genetic characteristics of their children. Currently it is possible to test embryos created by IVF to find out which embryos carry certain disease-causing genes. Embryos found to carry the genes are not implanted. Professor Savulescu argues the technique should be further developed to allow parents to select genes for anything ranging from hair colour to intelligence or sporting ability.

Source: *Sydney Morning Herald*, 6 January 2008.

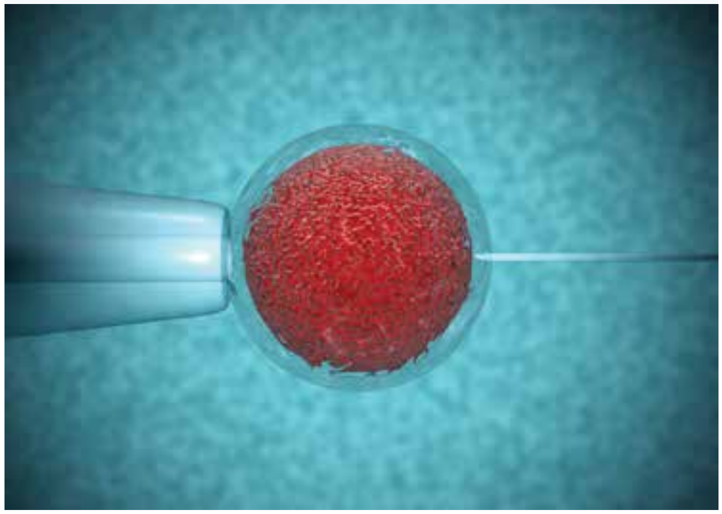
Dr Kakoli Ghosh Dastidar works in a clinic in India where local women are paid to act as surrogates for other couples.

A surrogate mother having an ultrasound

Should parents have the right to select certain characteristics in their children?

2.10.6 Freezing eggs is ‘highly experimental’

A human egg (right) shown next to the tip of a thin glass pipette



The option of freezing some eggs is increasingly offered to women for a variety of reasons. Treatment for certain types of cancer can make women infertile or damage their eggs. Having some eggs collected and frozen before starting cancer treatment would give these women a chance to have children after they recover from the cancer. For women who have not met the right partner or do not feel ready to be mothers by the time they reach their late thirties, egg freezing might offer the possibility of extending a woman’s reproductive years. The chance of producing a baby from frozen eggs is not very high at this stage. In 2007 the American Society for Reproductive Medicine calculated that for every 100 frozen and thawed eggs only 2 to 4 pregnancies would result. Eggs are more difficult to freeze than semen or embryos because they contain more water and ice crystals can form inside the egg.

Source: *Sydney Morning Herald,* 26 October 2007.

2.10.7 Parents sue over IVF son: report

Treatment for haemophilia usually includes regular transfusions of a product obtained from donated blood.

A Victorian couple are suing doctors at an IVF clinic. The couple decided to use IVF to conceive their child because they wanted to avoid giving birth to a child with haemophilia. The mother knew she was carrying a gene for haemophilia. Haemophilia is a disease where blood does not clot properly. A person who has severe haemophilia will usually require a transfusion of a special component of blood any time they have even a minor injury such as a cut or bruise. If a woman is a carrier for haemophilia, she does not have haemophilia herself. If she has a daughter and the father does not have haemophilia, the daughter will not have haemophilia either. If the same couple have a son, however, there is a 50 per cent chance that he will have haemophilia.

The couple used IVF because they wanted the doctors to test the embryos to find out if they were boys or girls before transferring them to the mother’s womb. The doctors made a mistake and transferred a male embryo. The couple gave birth to a son who has severe haemophilia.

The couple are suing the doctors who carried out the IVF treatment. They are arguing that the unexpected arrival of a boy caused them shock and anxiety. They also want to be compensated for the cost of medical treatment for their son as well as the pay they have lost as a result of not being able to go to work when their son has needed treatment.

Source: ABC News, 23 March 2008.

2.10 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the following terms: surrogacy, surrogate mother, altruistic, commercial.
2. **Outline** some situations where women may consider having their eggs frozen.
3. What is the chance of producing a baby from a frozen egg? Why is the success rate so low?

Think

4. **Discuss** whether there should be an age limit for IVF treatment. Should this age limit apply to the mother only or to both parents? **Justify** your answer.
5. Carry out a PMI on the following statements:
6. 'A woman should be allowed to use her dead husband's sperm to conceive a child'.
7. 'Commercial surrogacy using overseas surrogates should be illegal in all Australian states'.
8. 'Commercial surrogacy using Australian surrogates should be legal'.
9. Using IVF and genetic testing it is currently possible for parents to choose certain characteristics in their children. The technology can be used to screen out certain genetic diseases and to select the sex of the child. In the future it may be possible to select a much greater number of characteristics.
   (a) **Discuss** whether this particular technology is harmful or beneficial.
   (b) Should parents be allowed to select any characteristics for which there is a test available or should there be restrictions on the characteristics that parents can select? **Justify** your answer.
   (c) IVF and genetic testing are expensive procedures, so they may not be available to poorer couples. **Explain** how this could impact on society.

Investigate

10. Use EBSCO or another database to locate other news stories about reproductive technology. **Summarise** the key points in each article.

2.11 Review

2.11.1 Infectious diseases

- **distinguish** between infectious and non-infectious diseases **2.2**
- **recall** examples of diseases caused by each of the following types of pathogens: bacteria, fungi, viruses and prions **2.2**

2.11.2 Non-infectious diseases

- **compare** the leading causes of deaths in Australia to other parts of the world **2.3**
- **identify** some lifestyle risk factors for some of the leading causes of death **2.3**
- **describe** contributions by Australian scientists in the area of Indigenous health **2.3**

2.11.3 The immune system

- **describe** the role of the skin, mucus membranes, chemical barriers and other components of the first line of defence against diseases in the human body **2.4**
- **outline** how inflammation, fever and phagocytosis assist in the maintenance of health **2.4**
- **explain** how immunity against a particular pathogen is acquired **2.5**

2.11.4 Vaccination

- **evaluate** the advantages of vaccination **2.6**
- **outline** the work of two Australian scientists that have contributed to immunology research **2.6**

2.11.5 Epidemics

- **define** the terms epidemic and pandemic 2.7
- **outline** the type of research that is carried out when new diseases emerge and spread 2.7
- **recall** examples of animal and plant diseases 2.7

2.11.6 Reproduction

- **recall** the name and function of the organs of the male and female human reproductive system 2.8
- **describe** some birth control techniques 2.8
- **evaluate** the benefits and disadvantages of a number of reproductive technologies 2.9, 2.10
- **assess** the impact of reproductive technologies on society 2.9, 2.10
- **investigate** how issues relating to reproductive technologies have been presented in the mass media 2.10

Individual pathways

ACTIVITY 2.1	ACTIVITY 2.2	ACTIVITY 2.3
Revising medical science doc-10635	Investigating medical science doc-10636	Investigating medical science further doc-10637

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FOCUS ACTIVITY

Write an exposition based on the following statement using at least five examples from this topic: 'New technology leads to scientific discoveries, which in turn can be used to address problems in society'.
Access more details about focus activities for this topic in the Resources tab (doc-10634).

assesson

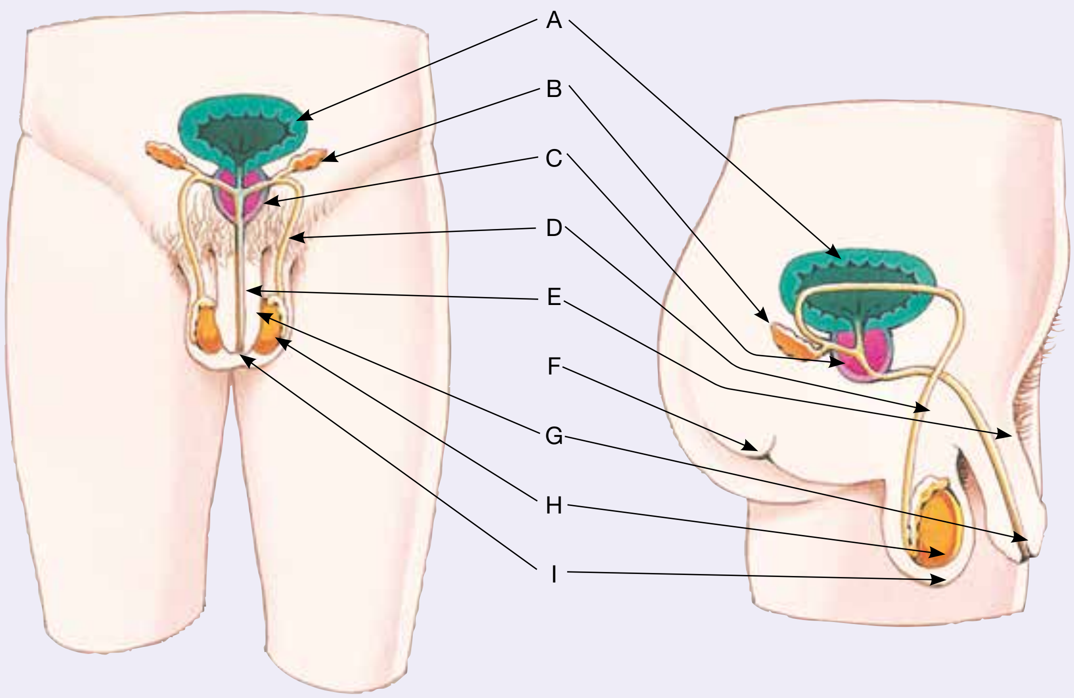
2.11 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

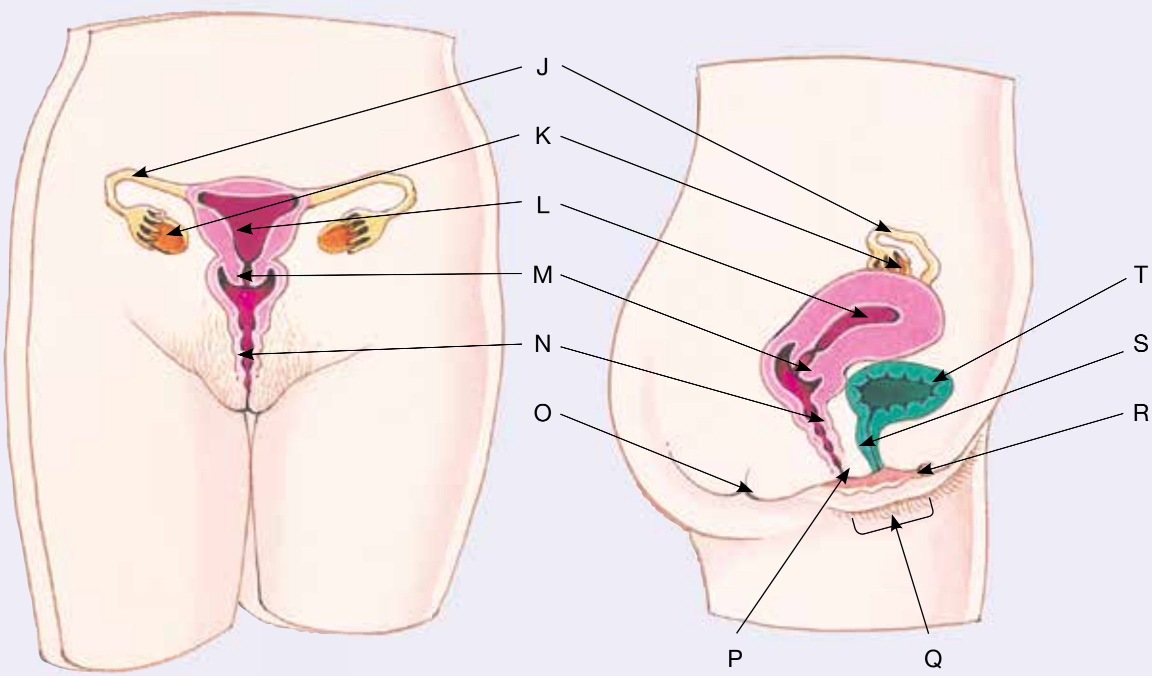
1. Write down two examples of:
   (a) non-infectious diseases
   (b) bacterial diseases
   (c) viral diseases
   (d) prion diseases.
2. List three lifestyle factors that increase the risk of cardiovascular disease.
3. How could a researcher investigate whether an exercise program consisting mainly of walking is more effective at reducing the risk of cardiovascular disease than an exercise program consisting mainly of weight lifting?
4. (a) **Explain** what it means to be immune to a disease.
   (b) How do vaccines provide immunity to particular diseases?
5. **Explain** the role of scientific research in controlling the spread of emerging diseases such as SARS.
6. (a) Which pathogen causes AIDS?
   (b) How is AIDS transmitted?
   (c) **Describe** the effect of HIV on the body.

7. (a) **Identify** the parts labelled A–T in the diagrams below.
(b) Write the function of the parts labelled B, D, G, H, I, K, L and N in the diagrams below. Present your answers in a table.

The male reproductive system



The female reproductive system



8. (a) Give an example of a plant and animal disease.
   (b) **Explain** why it is important to control the spread of animal and plant diseases.
9. Match the contraceptives below with the way they prevent conception and their effectiveness.

Contraceptive	How it prevents conception	Effectiveness
Condom with spermicide	Prevents ova from developing	Extremely effective
Diaphragm without spermicide	The fallopian tubes or vas deferens are cut and sealed	Moderately effective
Daily contraceptive pill	Keeps sperm and semen from entering the woman's vagina after ejaculation	Highly effective
Surgical: vasectomy and tubal ligation	Prevents sperm cells from reaching the cervix	Highly effective

10. Briefly **outline** what the following reproductive technologies involve:
    (a) artificial insemination
    (b) IVF
    (c) surrogacy (using egg and sperm from the parents who will raise the child).
11. Choose one of the reproductive technologies described in this topic and **outline** some of the ethical issues raised by this technology.
12. **Explain** why artificial insemination is proving to be a useful technique for zoos and other animal research centres fighting to boost the numbers of some endangered species. Give as many reasons as you can.

Test yourself

1. Which of the following is a macroscopic parasite?
   (a) Flea
   (b) HIV
   (c) *Plasmodium* (a protozoan)
   (d) *E.coli* (a bacterium) **(1 mark)**
2. Which of the following is part of the first line of defence?
   (a) Fever
   (b) Inflammation response
   (c) Mucous membranes
   (d) Antibodies **(1 mark)**
3. Which of the following is NOT a type of white blood cell?
   (a) B lymphocytes
   (b) Helper-T cells
   (c) Phagocytes
   (d) Platelets **(1 mark)**
4. Which statement is correct:
   (a) An epidemic is localised to a particular region or country whereas a pandemic involves a larger area of the world.
   (b) An epidemic is when a disease spreads rapidly through a population whereas a pandemic is when the disease is brought under control.
   (c) An epidemic is when an infectious disease spreads rapidly whereas a pandemic involves a non-infectious disease.
   (d) An epidemic lasts less than one year whereas a pandemic can last for a number of years. **(1 mark)**
5. Which of the following statements best describes the IVF process?
   (a) Semen from a donor male is injected into the female's vagina
   (b) Hormone treatment is used to stimulate a woman's ovaries
   (c) A semen sample is combined with one or more eggs outside the body
   (d) A woman carries a child conceived from another couple's egg and sperm in her womb. **(1 mark)**

6. Copy and complete the table below. **(6 marks)**

Name	1st, 2nd or 3rd line of defence?	Role played in the maintenance of health
Skin		
Mucous membranes		
Phagocytes		
Fever		
B lymphocytes		
T lymphocytes		

7. **Describe** a technological advance that has madeit possible to detect abnormalities in unborn babies. **(2 marks)**
8. **Discuss** the implications of this type of technology on society. **(4 marks)**

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Complete this digital doc: Worksheet 2.5: Medical science: puzzles (doc-12745)

Complete this digital doc: Worksheet 2.6: Medical science: summary (doc-12746)

TOPIC 3
Electricity at work

3.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

3.1.1 Why learn this?

Imagine what life would be like without mobile phones, television, DVDs, CDs, video cameras, computers, video games or calculators. You do not have to understand how all of these technologies work to use and enjoy them, but it is important to understand some of the basic principles behind electrical devices.

LEARNING SEQUENCE

Electrical devices are in huge demand and commonplace in homes today.

Electricity — it's everywhere!

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Think

Work in a small group to compile answers to each of the following questions.

1. Make a list of all of the electrical devices used in and around the home.
2. Which devices are designed:
   (a) to reduce the amount of effort needed to perform tasks done at home?
   (b) for heating or cooling?
   (c) for lighting?
   (d) for entertainment?
3. Which devices contain motors?
4. What is the purpose of fuses and circuit breakers?
5. Why should electrical appliances be used with caution in bathrooms?
6. In terms of electricity, what is the difference between an 18 W and a 14 W light globe?

At home

7. Which electrical appliances have plugs with three pins while others have two?
8. Find an appliance with an energy rating sticker. What information is contained on the sticker?
9. Compact fluorescent and LED globes have replaced traditional incandescent lights. Explain why.
10. If one of the light globes in your home breaks, the others continue to work when switched on. What does that tell you about the way that your home lighting circuits are designed?

Our energy future

Electricity is provided to the home and school via transmission lines.

11. (a) How is most of the electricity generated in New South Wales? Does this use a renewable or non-renewable energy source?
    (b) Brainstorm some other ways that electricity can be generated.

3.2 Electric circuits

3.2.1 Simple circuits

When you switch on a light, a television, a computer or a CD player, you are completing a pathway along which electrical energy flows. The pathway is called an **electric circuit**. All electric circuits consist of three essential items:

- a **power supply** provides the electrical energy
- a **load** (or loads) in which electrical energy is converted into other useful forms of energy
- a **conducting path** allows electric charge to flow around the circuit.

3.2.2 What is electricity?

The batteries (cells) used in torches and many other devices store chemical energy inside them. The chemical energy is transformed into electrical energy as a chemical reaction takes place inside the batteries.

Most household appliances do not rely on batteries but rather receive electrical energy from a power station via a power outlet.

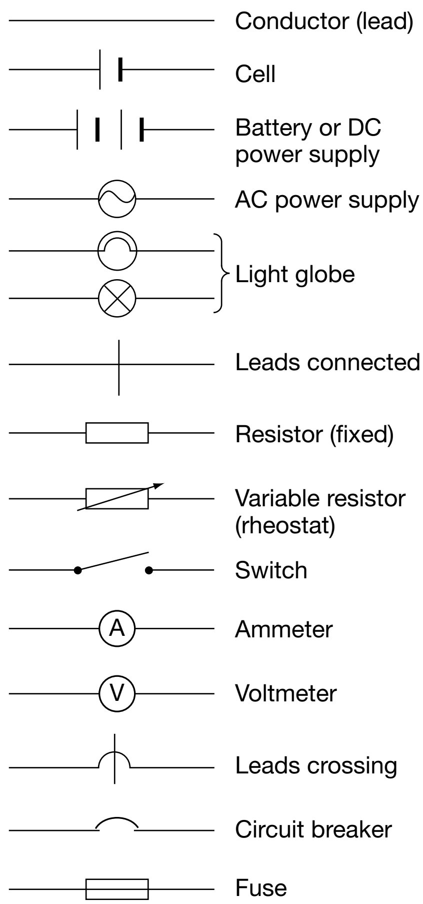
In electric circuits, electric charges travel around the circuit, gaining electrical energy from a power source and converting it to other useful forms in a load. To better understand the nature of the electricity in circuits it is important to grasp the concepts of electric current, voltage and resistance.

3.2.3 Current

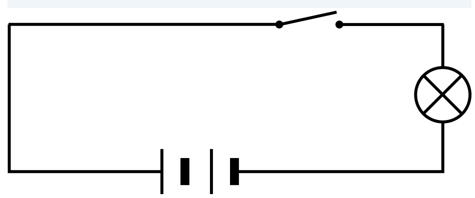
When a torch switch is clicked *on*, the light comes to life — what's happening? Pushing the button closes the switch in the torch circuit. This provides a complete (or closed) circuit through which electric charges, called electrons, can flow. This flow of charge is called an **electric current** (symbol, *I*). Electric current is measured in amperes (A) or amps for short, named after André Ampère (1775–1836), a French physicist and mathematician who is generally credited as one of the main discoverers of electromagnetism.

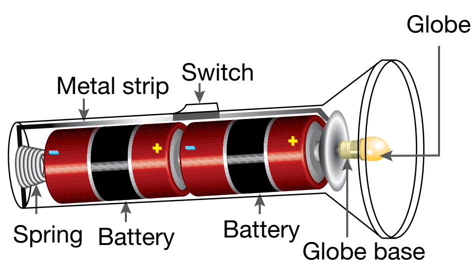
There are billions of electrons travelling around a circuit, each carrying an extremely small charge. If we were to quantify electric current in terms of individual electrons we would need to quote very large numbers indeed. Instead, scientists refer to the number of **coulombs** of charge flowing through a circuit. It's a little like referring to eggs in dozens rather than individually. A coulomb is equivalent to the charge of 6.2×10^{18} electrons. Consequently, the electric charge of a current of 1 ampere is equivalent to one coulomb of charge (or 6.2×10^{18} electrons) travelling around the circuit per second, so 2 amperes = 2 coulombs per second etc.

Symbols for common circuit components



Circuit diagram for a torch





3.2.4 Voltage

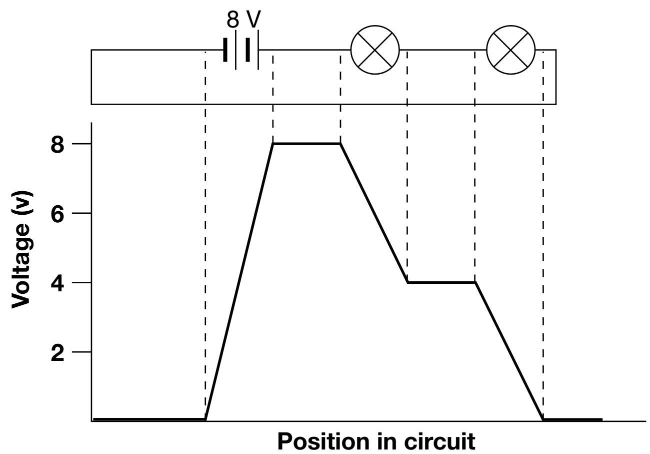
Voltage is a measure of the electrical energy carried by the charges in a circuit. Voltage (*V*) is measured in volts (also symbol; V) and named after Alessandro Volta (1745–1827), an Italian physicist renowned for the development of the first electric cell in 1800.

Voltage is sometimes referred to as potential difference because it measures the change in the potential, or stored electrical energy of the charges as they move from the start to the end of a circuit. For example, a 3-volt torch battery supplies the equivalent of 3 joules of energy per coulomb of charge in the circuit of the torch.

Electric charges gain electrical energy as they pass through the power supply in a circuit. They lose the same amount of electrical energy as they move through the rest of the circuit and this energy is transformed to other forms. This means that the voltage gain across the terminals of the power supply is equal to the total voltage drop across the rest of the circuit.

Components like light globes in an electrical circuit act as loads. It is in each of the loads that the electrical energy carried by the charges is transformed into other forms. In the example of a light globe, electrical energy is transformed into light and heat as the filament, a coiled tungsten wire, glows brightly when it gets hot. In a hair dryer there are two loads: a heater and a fan.

Voltage rises and falls in a simple circuit.



3.2.5 Resistance

Resistance (R) is a measure of how much a load restricts and reduces the flow of current. Resistance is measured in ohms (Ω), named after Georg Ohm (1789–1854), a German physicist who described the relationship between the voltage, current and resistance in an electrical circuit. In an efficient electric circuit, most of the electrical energy provided by the power supply is transformed in the loads. Little of the electrical energy is transformed in the conducting wires because they are made of metals like copper which have little resistance.

A summary of variables associated with electric circuits and their units of measurement

Variable		Unit	
Name	Symbol	Name	Symbol
Voltage	V	Volts	V
Current	I	Amperes	A
Resistance	R	Ohms	Ω

3.2.6 A useful analogy

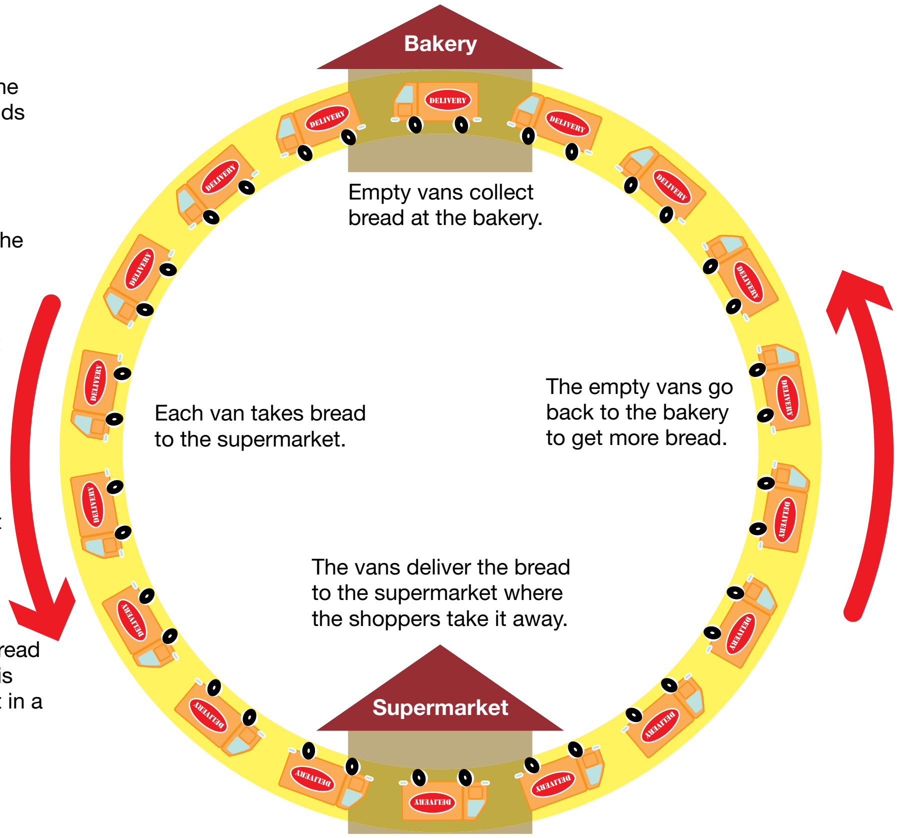
To understand the concept of voltage, current and resistance in an electric circuit it is helpful to provide an analogy, or real-life comparison.

A bakery supplying bread to a supermarket is a good analogy for an electric circuit:

- The battery provides energy just like the bakery provides loaves of bread for delivery to supermarkets.
- The energy is carried around a circuit by electrical charges; similarly, the bread is carried around by delivery vans.
- The charges (electrons) are already there in the conducting wires of a circuit, just as the delivery vans are there waiting to deliver bread.
- The flow of charges is called an electric current and is like the line of moving delivery vans.
- The electrical energy carried by the charges is 'given out' in the bulb as heat and light and the charges return to the battery to collect more energy; similarly, the bread carried by the vans is sold to the supermarket and the vans return to the bakery to collect more bread.
- The resistance in the electric circuit due to the load slows the current in the same way that delivery to each supermarket slows down the movement of delivery vans.
- The more loads in an electric circuit, the more resistance and the less current, just as the more supermarkets that need to be visited by the vans, the slower the vans travel.

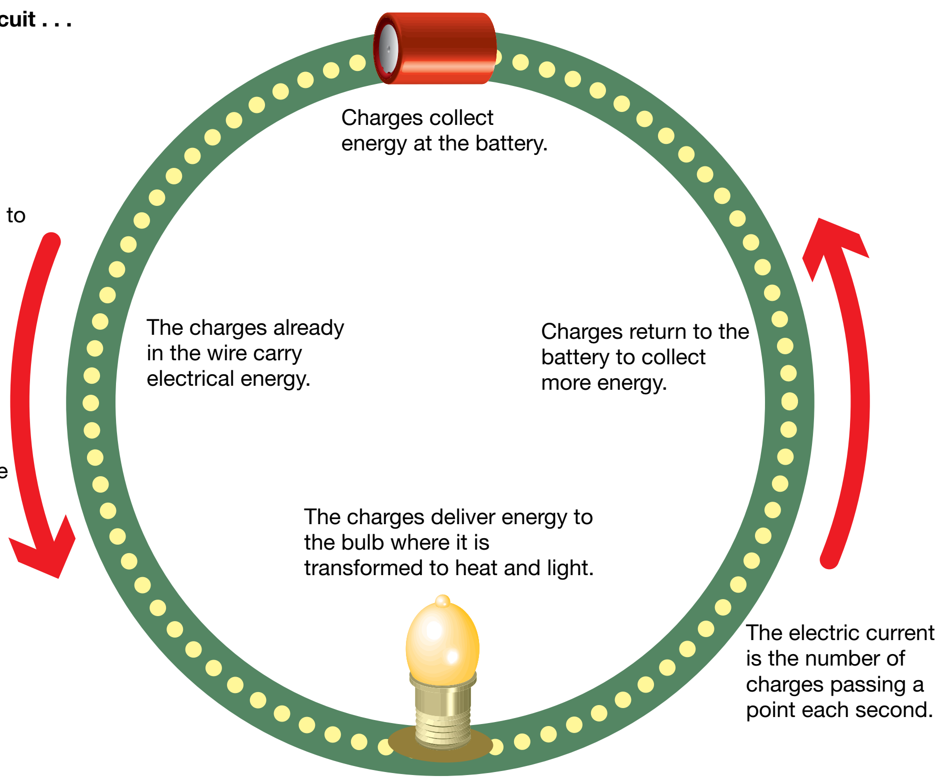
A bakery supplying bread to a supermarket can be an analogy for an electric circuit.

1. The bakery manager loads the bread onto the vans and sends them off.
2. As soon as the vans start to move, bread is delivered to the supermarket.
3. All the delivery vans move at the same speed.
4. If the manager speeds the vans up, more bread is delivered to the supermarket in a certain time.
5. If the manager loads more bread on to each van, more bread is delivered to the supermarket in a certain time.



Relating this to an electric circuit . . .

1. The battery provides energy and allows the charges to move.
2. As soon as the charges start to move, the bulb lights up.
3. All the charges move at the same speed.
4. If the charges speed up more energy is delivered to the bulb in a certain time.
5. If more energy is carried by each charge, more energy is delivered to the bulb in a certain time.



It is important to understand that the charges travelling through an electric circuit are present in the conducting wires already. A circuit's power source merely provides these charges with the energy to travel around the circuit. It's a little like the water in your water pipes. When you turn on a tap, you do not need to wait for the water to travel from the reservoir to the tap. Rather, the water is already in the pipes under pressure. Turning the tap on merely releases the water already in the system just like closing the switch in an electric circuit.

INVESTIGATION 3.1

A water analogy

AIM: To model an electric current

You will need:

long rubber hose
stopwatch

- Turn off the lights in the classroom then turn the light switch back on and time how long it takes for the electrical current to reach the lights.
- Attach the rubber hose to a tap and run it to a sink as far away as possible.
- Turn the tap on and time how long it takes for water to reach the sink. Record the time taken.
- Repeat this experiment, but this time start with the hose already full of water.

Discussion

1. Which is the better analogy for an electrical current, the current of water when the hose is full of water or when the hose is empty? Explain why.
2. In this analogy what do each of the following represent:
   (a) the water?
   (b) the hose?
   (c) the tap?
3. What aspect of an electrical circuit does this analogy not represent well?

3.2.7 Measuring current and voltage

A current of water in a river can be measured by determining the volume of water that passes a particular point every second. Similarly, the size of the electric current in a circuit can be measured by determining the amount of electric charge passing a particular point in an electrical circuit every second.

An **ammeter** is used to measure the size of electric current flowing in an electrical circuit. An ammeter measures electric current in amperes (A). Sensitive ammeters can measure currents as small as thousandths of an ampere, (milli-amperes mA), or even millionths of an ampere, (micro-amperes μA).

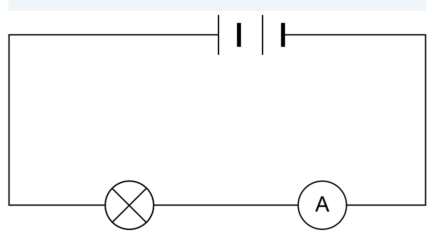
An ammeter is used to measure electric current.

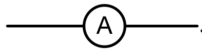
Using an ammeter

Many ammeters used in school laboratories have one black, negative terminal and two or more red, positive terminals. Remember the following points when using ammeters.

- The positive terminal of the ammeter should always be connected **in series** so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Always read an ammeter from directly in front. The error obtained by not reading from directly in front is called a **parallax error**.
- If the ammeter has more than one red terminal:
- Use the positive terminal with the highest value first. If the measured current in your circuit is too small to be detected on this scale, change the connection to the positive terminal with a smaller value.

Circuit diagram showing how an ammeter is connected to measure the electric current through a light globe

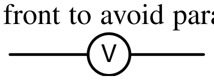


- Read the scale that matches the positive terminal used.
- An ammeter is represented by the symbol .

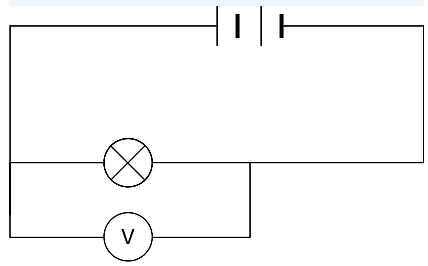
Using a voltmeter

A voltmeter is used to measure the voltage gain across the terminals of a power supply or the voltage drop across a load in an electric circuit. Voltage is measured in volts (V).

Like ammeters, most voltmeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. Remember the following points when using voltmeters.

- A voltmeter should be connected in **parallel** with the component of the circuit across which the voltage is being measured. The positive terminal should always be connected so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured voltage in the circuit is too small to be detected on this scale, change the connection to the positive terminal with a smaller value.
- Read the scale that matches the positive terminal used.
- Always read a voltmeter from directly in front to avoid parallax error.
- A voltmeter is represented by the symbol 

Circuit diagram showing how a voltmeter is connected to measure the voltage drop across a light globe



3.2.8 Understanding resistance

The negatively charged electrons moving in an electric circuit have to make their way around the atoms in the connecting leads and components that make up the circuit. Electrical resistance is a measure of how difficult it is for electrons to flow through part of a circuit. The resistance to the flow of electric charge limits the electric current, just as the resistance due to a crowded corridor limits the number of students who can pass through in a given time interval. Electrical resistance also determines how much energy is lost through transformation to heat, light etc. by the electric charges as they move through a circuit.

Conductors have very little resistance. They allow large electric currents to flow with little loss of energy. **Insulators** have a very large electrical resistance. They allow very little electric current to flow.

The value of the resistance (R) of any part of an electric circuit can be calculated by the following formula, where V is the voltage drop in volts and I is the electric current in amperes.

$$R = \frac{V}{I}$$

A torch globe carrying an electric current of 0.2 A with a voltage drop of 3 volts therefore has a resistance of:

$$R = \frac{V}{I} = \frac{3}{0.2} = 15\,\Omega.$$

INVESTIGATION 3.2

Current and voltage in a circuit

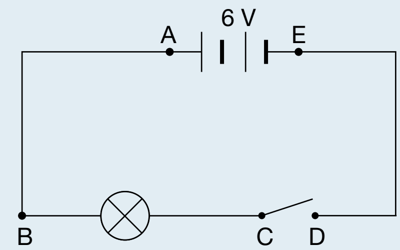
AIM: To investigate the electric current and voltage at various points in a circuit

You will need:

DC power supply (set to 6 volts)
12-volt light globe and holder
3 connecting leads with alligator clips or banana plugs

switch
ammeter
voltmeter

- Set up the circuit shown in the diagram at right. Make a copy of the table below in which to record your measurements.
- With the switch open, connect the ammeter in series at each of the points A, B, C, D and E to measure the electric current at these points. Record your measurements in the table.
- With the switch open, measure the voltage across each of the following components by connecting the voltmeter parallel to:
  (a) the power supply (across points A and E)
  (b) the light globe (across points B and C)
  (c) the switch (across points C and D)
  (d) one of the connecting wires (across points A and B).
- Close the switch.
- Repeat your measurements of electric current at each of the points A, B, C, D and E using the ammeter.
- Repeat your measurements of voltage across the power supply, the light globe, the switch and the connecting wire using the voltmeter.



Discussion

1. Compare the electric current when the switch is opened to when it is closed.
2. Were there any differences in the size of electric current at each of the five points when the switch was closed? Explain.
3. Across which parts of the circuit were there significant voltage drops? Explain.
4. How does the voltage across the terminals of the power supply compare with the voltage across the light globe when the switch is closed? Explain.
5. Where is most of the electrical energy provided by the power supply used?

Currents and voltages around a simple circuit

	Using the ammeter		Using the voltmeter	
	Location in circuit	Electric current (A)	Item	Voltage (V)
Switch open	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting wire	
	E			
Switch closed	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting wire	
	E			

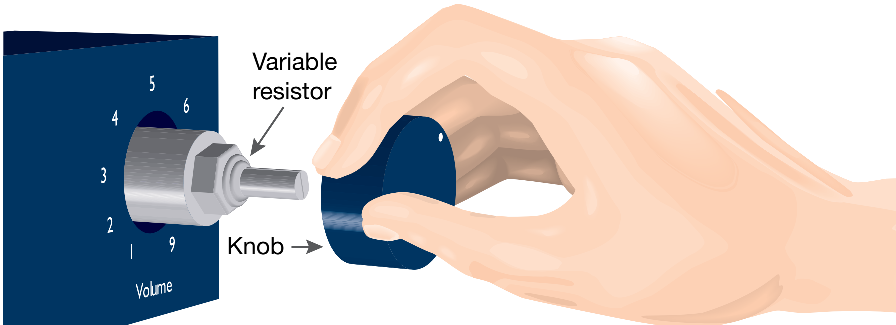
3.2.9 Controlling the flow

When you turn down the volume of a radio or television, you are changing the voltage and current available to the electric circuits inside. The volume switch acts as a **variable resistor**.

Resistors are used in electric circuits to control the voltage and current. They can have a fixed resistance or a variable resistance like those in volume controls. The photograph at right shows some different types of resistors. The two tall cylindrical resistors are a type of variable resistor used in volume dials.

A range of resistors

A variable resistor in a stereo system



The knob sits on the stem of the variable resistor. When you turn the knob, the stem of the variable resistor rotates, changing its resistance and controlling voltage and current.

INVESTIGATION 3.3

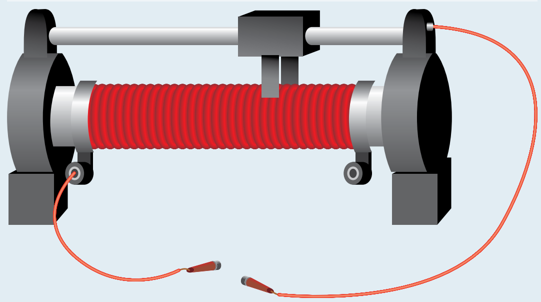
Variable resistance

AIM: To investigate the effect of a variable resistor in a circuit

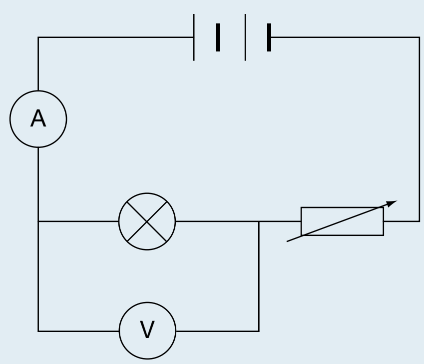
You will need:

DC power supply
ammeter
variable resistor (rheostat)
5 connecting leads with alligator clips or banana plugs
ruler
12-volt light globe
voltmeter

Connecting to a variable resistor



- Set up the circuit shown in the diagram below right. Turn the DC power source to 10 V. The variable resistor (see above right) is connected in series with the light globe.
- Move the sliding part of the variable resistor so that the voltage drop across the light globe is at a maximum.
- Measure the current through the circuit and the voltage across the light globe and record these values in a suitable table.
- Slide the variable resistor 3 cm from the starting point and repeat these measurements.
- Continue to take readings at 3 cm intervals until you reach the end of the variable resistor. Record your data in a suitable table.



Discussion

1. What evidence is there to suggest that at the start of the experiment the resistance of the variable resistor is at a minimum?
2. Explain what happens to the electric current flowing through the light globe as the resistance of the variable resistor increases.
3. Explain what happens to the voltage across the light globe as the resistance of the variable resistor increases.
4. Explain what happens to the brightness of the light globe as the resistance of the variable resistor increases.
5. What would you expect the sum of the voltage across the light globe and the voltage across the variable resistor to be? Explain.

3.2.10 Ohm's Law

In 1827, a German physicist, Georg Simon Ohm, discovered that the electric current in metallic conductors was proportional to the voltage drop across the conductor. That is, if the voltage was doubled, the current doubled. If the voltage was tripled, the current tripled. This relationship is known as **Ohm's Law**.

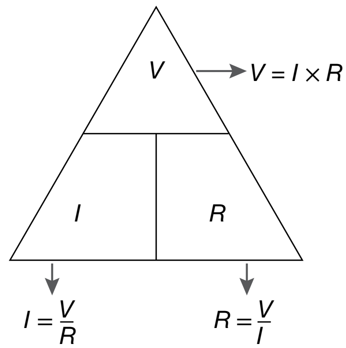
Materials that obey Ohm's Law are said to be ohmic. The fine filament in a light globe is not ohmic as it heats up. Metals and carbon are ohmic materials as long as the temperature remains fairly constant.

One way of working out whether a material is ohmic is to draw a graph of voltage drop versus electric current. Ohm's law is often defined by the equation:

$$R = \frac{V}{I}$$
$$\therefore V = IR$$

If the material is ohmic, a graph of V versus I yields a straight line because the resistance is constant.

Problems involving Ohm's Law can be calculated using this triangle. Place your finger over the variable that you wish to calculate.



INVESTIGATION 3.4

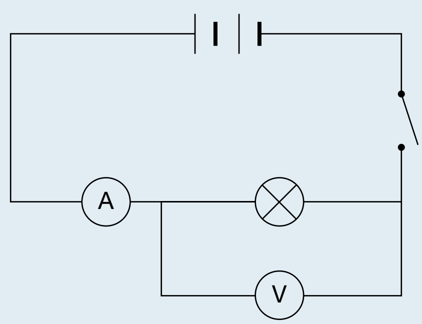
Calculating resistance

AIM: To calculate the resistance of a light globe using Ohm's Law

You will need:

DC power supply
12-volt light globe and holder
6 connecting leads with alligator clips or banana plugs
switch
ammeter
voltmeter

- Set up the circuit shown in the diagram at right and leave the switch open.
- Construct a table like the one given below to record your measurements.
- Set the power supply to 2 volts. Close the switch and quickly read the meters, recording the electric current and voltage drop in your table. Ensure that the electric current is recorded in amperes (not milli-amperes).
- Repeat the experiment with the power supply set to 4, 6, 8, 10 and 12 volts, each time quickly measuring and recording the electric current and voltage displayed on the meters.

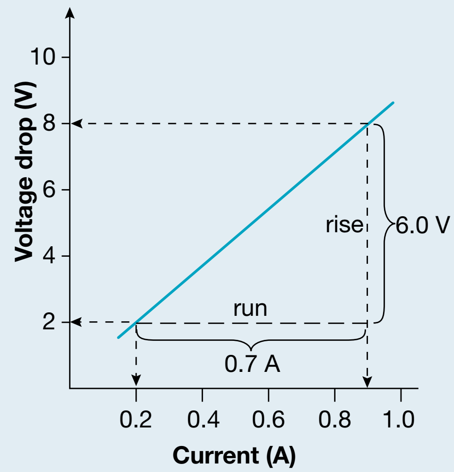


Power supply setting (V)	Electric current through the globe (A)	Voltage drop across the globe (V)
2		
4		
6		
8		
10		
12		

- Plot a graph of current (*x*-axis) against the voltage drop (*y*-axis) for the light globe. You might like to use a spreadsheet for this purpose. Draw a line of best fit (trend line) to display any pattern in your data.

Discussion

1. Is your line of best fit a straight line or a curve? Explain why.
2. Calculate the resistance of the light globe using Ohm's Law. One way of doing this is to calculate the resistance using *V* and *I* values several times and finding an average, but this treats each pair of values as equally valid even though some may be discrepant (also called outliers). A more accurate way to calculate the average resistance is to use the gradient of your graph (where the line of best fit is a straight line). An example is given at right.



$$\text{Resistance} = \text{gradient} = \frac{\text{rise}}{\text{run}}$$

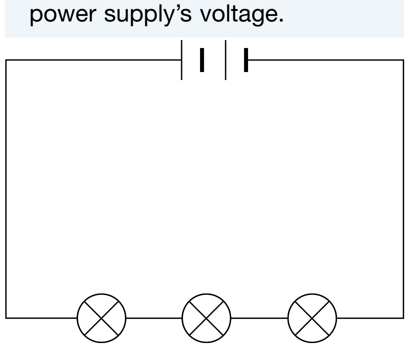
$$\text{Resistance} = \frac{V}{I} = \frac{6.0\text{ V}}{0.7\text{ A}} = 8.6\ \Omega$$

3.2.11 Series and parallel circuits

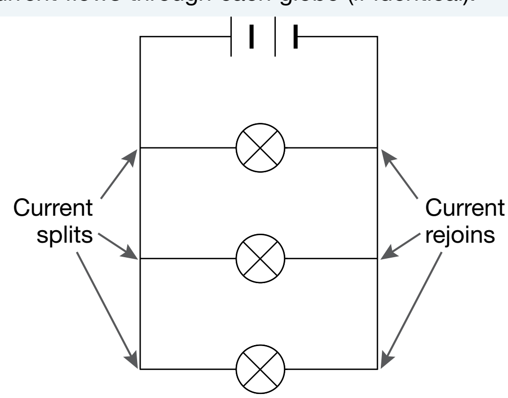
There are two ways that components can be connected in a circuit, series and parallel. In a series circuit the components are connected one after another in a row. As a result, the same current flows through each component. However, the voltage provided by the power supply is shared between each of the components.

In a parallel circuit the components are connected in separate branches. As a result, the current is divided between each of the components in the separate branches but each branch of a parallel circuit uses the full voltage provided by the power supply.

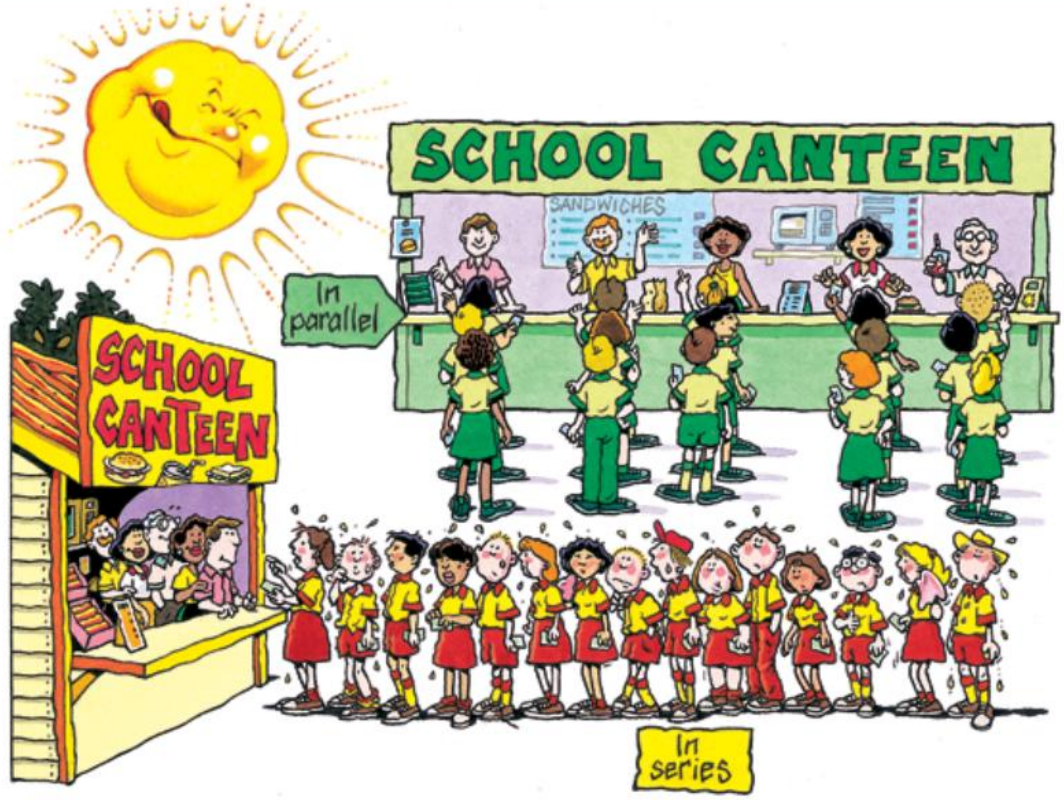
Three light globes connected to a power supply in series. The same current flows through each globe. Each globe, if identical uses one-third of the power supply's voltage.



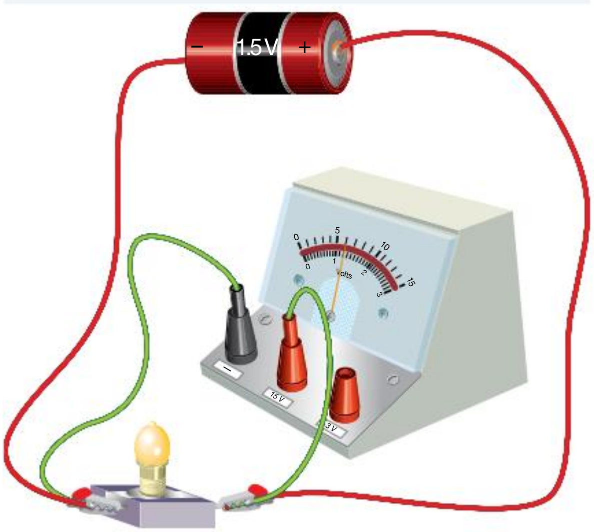
Three light globes connected to a power supply in parallel. Each globe uses the full voltage of the power supply. One-third of the current flows through each globe (if identical).



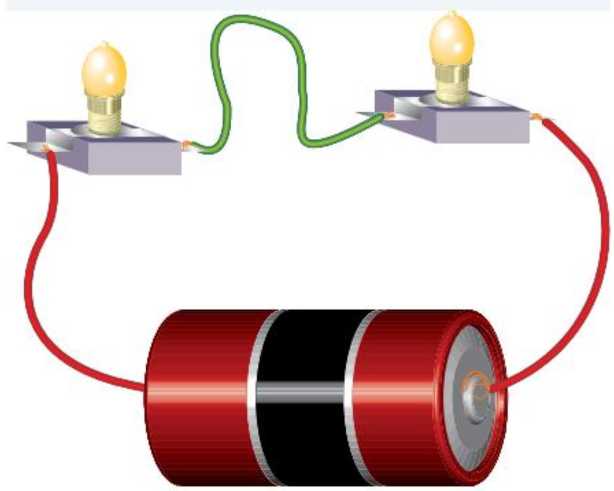
In a parallel queue of students, the congestion is reduced and they will be served more quickly. Similarly the total resistance in a circuit is reduced when the components are connected in parallel and this increases the total current.



How to measure voltage across one globe



Two globes connected in series



INVESTIGATION 3.5

Series circuits

AIM: To investigate the current and voltage in a series circuit

You will need:

DC power supply (set to 6 volts)

three identical 12-volt light globes and holders

5 connecting leads with alligator clips or banana plugs
ammeter
voltmeter

- Make a copy of the table below.
- Set up each of the circuits described in the table. Draw a diagram of the circuits in your workbook. Include the ammeters and voltmeter in your diagrams to show how the current flowing from the power supply and the voltage across one of the globes were measured.

Current and voltage in series circuits

Circuit description	Current (mA)	Voltage (V)
One light globe (globe X) connected to a 6-volt power supply		Globe X: ________ Power supply: ____
Two light globes (globes X and Y) connected in series with a 6-volt power supply		Globe X: ________ Globe Y: ________ Power supply: ____
Three light globes (globes X, Y and Z) connected in series with a 6-volt power supply		Globe X: ________ Globe Y: ________ Globe Z: ________ Power supply: ____

- Use the ammeter to measure the electric current flowing through each circuit. Place the ammeter in series with the light globes in each circuit so that the positive terminal is connected directly to the positive terminal of the power supply.

CAUTION: Check that the ammeter is connected properly. Check with your teacher if you are not sure.

- Use the voltmeter to measure the voltage drop across the power supply and each of the light globes in each circuit.
- Record all of your measurements in the table.
- While the third circuit is set up and switched on, unscrew one of the globes from its holder, if not too hot, and observe what happens.

Discussion

1. What happens to the electric current flowing through the circuit as more globes are added in series? Explain why this happens.
2. Why was it not necessary to separately measure the electric current flowing through each globe when two or three globes were connected in series?
3. What is the sum of the voltages across the globes in each of the three circuits?
4. How much voltage is 'lost' across each globe in the third circuit? Where has this electrical energy gone?
5. Make a general statement about voltage drops across light globes connected in series.
6. Make a general statement about electric current flowing through light globes connected in series.
7. Explain what happens to the other lights in series, if one of the lights breaks.
8. What happens to the brightness of the globes as more globes are added in series?

INVESTIGATION 3.6

Parallel circuits

AIM: To investigate the current and voltage in a parallel circuit

You will need:
DC power supply (set to 6 volts)
three identical 12-volt light globes and holders
5 connecting leads with alligator clips or banana plugs
ammeter
voltmeter

- Make a copy of the results table given below to record your measurements.

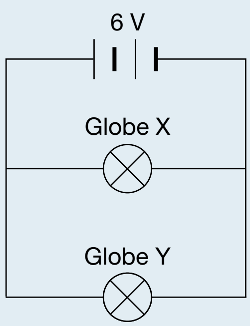
Current and voltage in circuits 1 and 2

Circuit	Current (mA)	Voltage (V)
Circuit 1	Globe X: _______________ Globe Y: _______________ Power supply: __________	Globe X: _________ Globe Y: _________ Power supply: _____
Circuit 2	Globe X: _______________ Globes Y and Z: ________ Power supply: __________	Globe X: _________ Globe Y: _________ Globe Z: _________ Power supply: _____

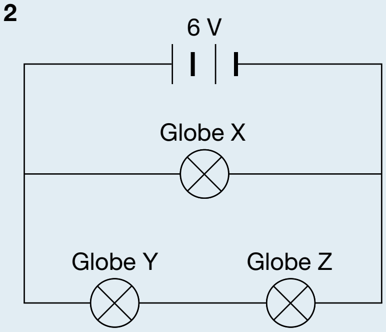
- Set up the circuits shown in the diagrams below. Observe whether adding the second globe in circuit 1 affects the brightness of the first globe (globe Y).
- Use the ammeter to measure the electric current flowing from the power supply and into each of the light globes in each circuit.

Parallel circuits

Circuit 1

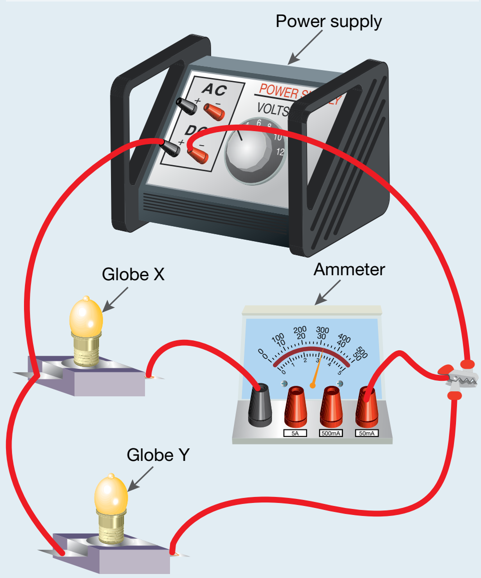


Circuit 2



CAUTION: Check that the ammeter is connected properly. Check with your teacher if you are not sure. Connecting the ammeter to measure the current in a parallel branch is tricky — see the diagram at right.

Connecting an ammeter to measure the current in a parallel branch of a circuit containing globe X



- Use the voltmeter to measure the voltage drop across the power supply and across each of the light globes in each circuit.
- While circuit 2 is set up and switched on, unscrew Globe X from its holder, if not too hot, and observe what happens.

Discussion

1. What is the sum of the currents flowing through globes X and Y in circuit 1?
2. What happens to the electric current flowing from the power supply when it meets a 'fork' in the pathway?
3. In circuit 2, how does the voltage drop across globe Y compare with the voltage drop across globe X? Explain why this is the case.
4. Make a general statement about electric current flowing through light globes connected in parallel.
5. Make a general statement about voltage drops across light globes connected in parallel.
6. Explain what happens to other lights connected in parallel if one of the lights break.
7. Does adding a second globe in parallel to the first affect the brightness of the first globe? Explain.

3.2 Exercise: Remember and think

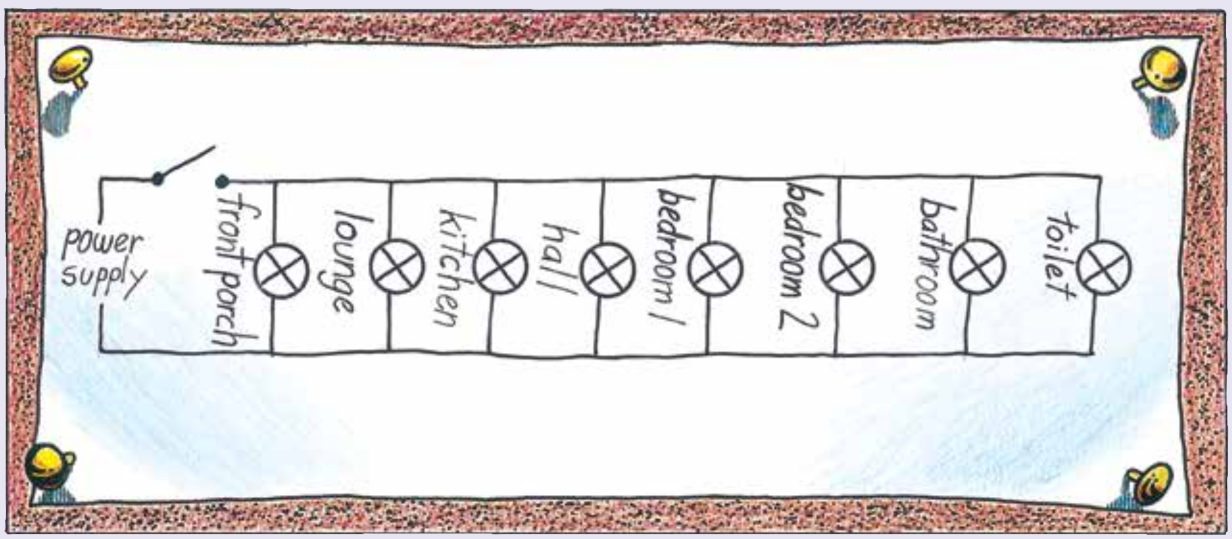
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** the three essential features of all electric circuits.
2. **Identify** the energy transformation taking place in a torch.
3. **Explain** why connecting wires are usually made of copper.
4. Draw a circuit diagram showing:
   (a) a battery connected to two light globes connected in series
   (b) a battery connected to two light globes connected parallel.
5. **Explain** why voltage is also known as potential difference.
6. **Define** the term 'electric current'.
7. **Identify** the device used to measure:
   (a) electric current
   (b) voltage.
8. Use Ohm's Law to **outline** the relationship between the voltage supplied to an appliance and the electric current flowing through that appliance.

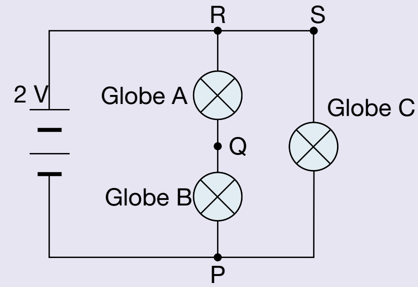
Think

9. A single light globe is connected to a power supply. Predict whether the brightness of this light globe will increase, decrease or remain the same when:
   (a) an identical light globe is connected in series with it
   (b) an identical light globe is connected parallel to it.
10. **Explain** two advantages of connecting the power outlets in a room of your home parallel to one another.
11. Redraw the circuit diagram from question 4(b), adding a switch that turns both light globes on or off at the same time.
12. An apprentice electrician has designed a lighting circuit diagram (shown below) for a new house. **Explain** what is wrong with this circuit design.

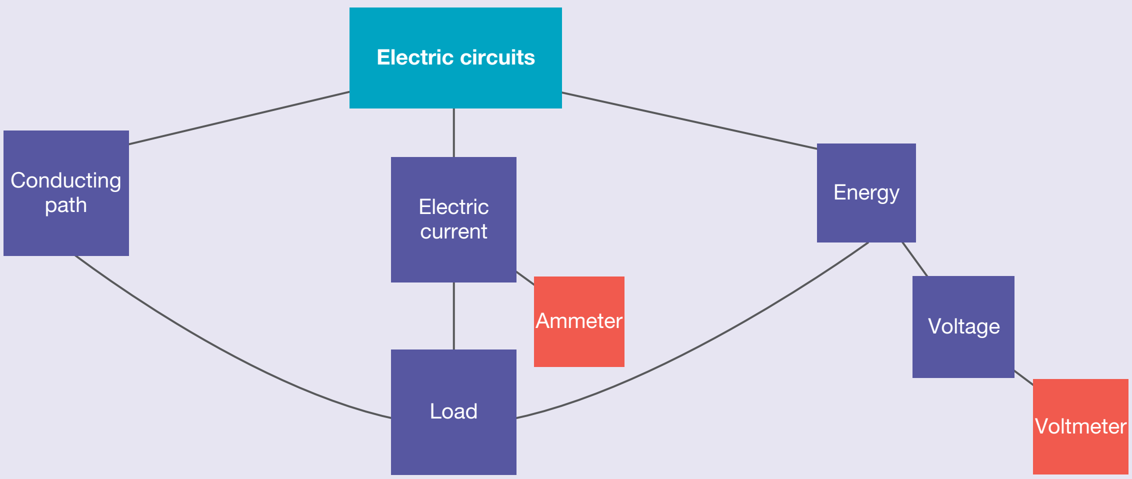


13. **Calculate** the voltage drop across a 100 Ω resistor when the electric current through it is 0.25 mA.
14. The electric current flowing through a light globe is 200 mA when the voltage across the globe is 1.5 V. When the voltage is increased to 3.0 V, the current is measured to be 360 mA.
   (a) **Calculate** the resistance of the light globe when the electric current is 200 mA.
   (b) **Explain** whether the light globe is ohmic.
15. When a light globe 'blows', the filament breaks. **Explain** what will happen if:
   (a) many light globes are connected in series and one blows
   (b) many light globes are connected in parallel and one blows.

16. In the circuit diagram at right, **predict** which of the light globes (A, B or C) will continue to glow if:
    (a) the filament in globe A breaks
    (b) the filament in globe B breaks
    (c) the filament in globe C breaks
    (d) a wire lead is connected between the points P and Q
    (e) a connecting lead is connected between the points P and R
    (f) a connecting lead is connected between the points P and S.

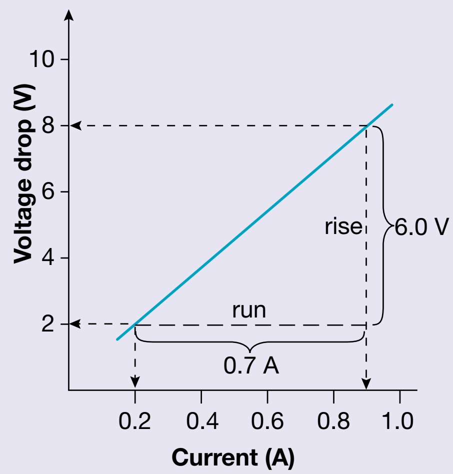


17. The incomplete concept map below represents some of the key ideas related to electric circuits. This concept map is just one way of representing ideas about matter and how they are linked. Copy and complete the concept map by writing suitable links between the ideas.



Using data

18. Answer these questions about the ohmic conductor described by the graph of voltage drop versus electric current at right.
    (a) **Predict** the voltage drop across the conductor when the electric current is 0.6 amperes.
    (b) **Predict** the electric current through the conductor when the voltage drop across it is 4 volts.
    (c) **Predict** the current through the conductor if it is supplied with 9 volts.
19. Read the measurement on the ammeter below accurately.



$$\text{Resistance} = \text{gradient} = \frac{\text{rise}}{\text{run}}$$

$$\text{Resistance} = \frac{V}{I} = \frac{6.0\ \text{V}}{0.7\ \text{A}} = 8.6\ \Omega$$

Investigate

20. Carry out an investigation to determine whether common loads like light globes and resistors are ohmic or non-ohmic. Present your data for each device as a line graph.
21. Research one of the following scientists and **outline** their contribution to our understanding of electricity:
    (a) André Ampere
    (b) Alessandro Volta
    (c) Georg Ohm.
    Present your research as a newspaper or journal article and emphasise the scientist's ground-breaking discoveries.
22. Use the **Hydraulic model of current** interactivity in the Resources tab to explore a DC circuit by adjusting the voltage and adding a combination of series and parallel resistors.
23. Use the **DC water analogy** weblink in the Resources tab to see a direct comparison between the flow of water and a DC circuit.

learnon RESOURCES — ONLINE ONLY

- **Explore more with this weblink:** DC water analogy
- **Explore more with this weblink:** Ohm's Law
- **Complete this digital doc:** Worksheet 3.1: Simple circuits (doc-12747)
- **Complete this digital doc:** Worksheet 3.2: Voltage and current (doc-12748)
- **Complete this digital doc:** Worksheet 3.3: Ohm's Law (doc-12749)
- **Complete this digital doc:** Worksheet 3.4: Series and parallel circuits (doc-12750)

3.3 Electricity at home

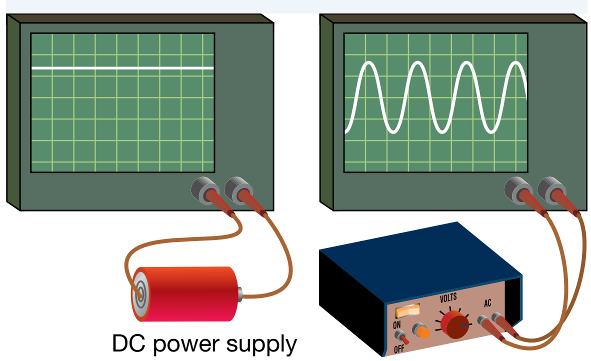
Science as a human endeavour

3.3.1 AC or DC

The electricity used to run many of the appliances in our homes is obtained by simply plugging a lead into a power point, also called a general power outlet (GPO) and switching it on. The electric current that flows from power points is not quite the same as the electric current that flows from a battery. Batteries provide a direct current (DC), meaning that a constant voltage is supplied causing the current to flow in one direction in a circuit. In a DC circuit, electrons carry electrical charge from the negative terminal to the positive terminal of the power source.

The current supplied to homes and available to appliances through power outlets is called alternating current (AC). As the name indicates, alternating current alternates or changes direction. In Australia, current alternates with a frequency of 50 Hz (50 times per second) and the voltage fluctuates from a positive to negative value with a voltage equivalent to 240 V.

The electrical voltage from a power supply can be displayed on a cathode ray oscilloscope (CRO). A DC power supply produces a constant voltage and a current that travels in one direction. An AC power supply produces a fluctuating voltage and a current that changes direction 50 times a second.



DC power supply

AC power supply

Alternating current, rather than direct current, is supplied by power stations because it is more efficient to distribute over large distances through the power grid.

A mobile phone charger

3.3.2 Appliance transformers

Many common electrical appliances are not designed to work on the 240 V AC electricity supplied to homes. These appliances contain devices called **transformers** that can increase or decrease the supplied voltage to the voltage required by the appliance. In addition, appliances that require DC electricity are supplied with an electrical device called a **rectifier** that converts AC to DC. Hence, the 240 V AC supplied to your home can supply a variety of appliances, each requiring a specific operating voltage. For example, mobile phone rechargers transform and rectify 240 V AC into the small DC current required to recharge the internal battery of the phone.

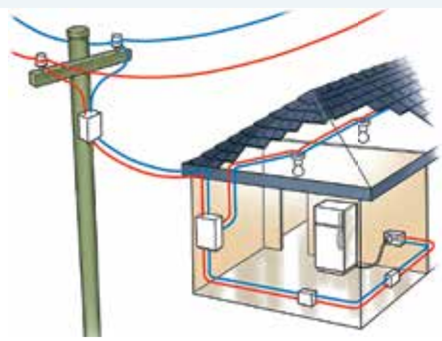
3.3.3 Electrical safety

Electricity is provided to homes through wires covered with plastic insulation. The wire that carries AC electricity to your house is called the **active** (often called the **live**) wire. This voltage alternates, providing the equivalent of 240 V. A second wire, called the **neutral** wire, completes the electrical circuit from your home to the electrical power grid that supplies your home and neighbouring streets.

The power cords that supply electrical appliances contain wires that have a double layer of insulation to prevent users from coming into contact with the wires. There is a plastic coating around each wire as well as a plastic cord around the two wires.

The electrical circuit supplying your home first passes through the electricity meter in the meter box to monitor your energy usage. From the meter box your home's main electric circuit splits into numerous parallel branches, each supplying different sections of your house. Some appliances such as hot water heaters and cooking stoves use particularly high electric currents and so may be on their own parallel branch. Often each room would be supplied with electricity by a separate parallel circuit, and within each room the lights may be on a separate branch to the power points. The advantage of this is that if a light blows in one room it won't affect the power points in that room or the lights in other rooms.

Active and neutral wires from transmission lines connect your home to the electricity grid.



3.3.4 Fuses, circuit breakers and safety switches

The separate circuits for each area of your home can be seen in the meter box. Each parallel circuit will contain a safety device called a **fuse** or a **circuit breaker**. Circuit breakers are installed in all new homes.

Electrical faults can occur in places you can't see. For example, the wires that connect to the power points in your home are hidden behind walls. These wires will usually carry

Circuit breakers within a meter box

electricity without overheating. But if a **short circuit** occurs, the wires could overheat and cause a fire.

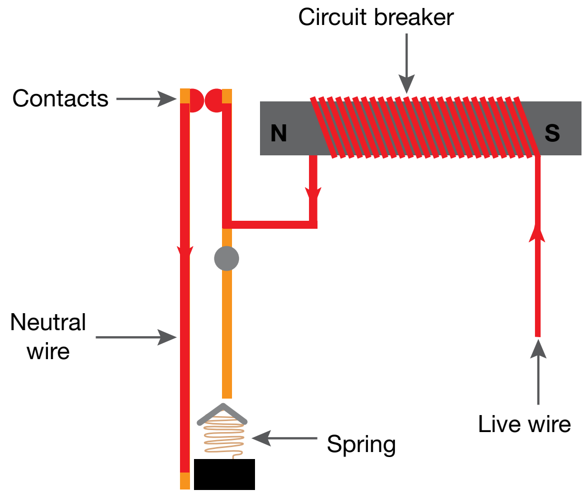
A short circuit occurs when an active wire comes into contact with a neutral wire without passing through a load. This may happen if the insulation around the wires frays and bare wires come in contact with one another. Without a load, the resistance in a short circuit is very small, resulting in an unusually high current that causes the conducting wires to heat up.

Fuses and circuit breakers prevent wiring from overheating due to short circuits or current surges from the mains supply. Fuses are made from a thin wire that heats up quickly when an unusually high current passes through it, causing the fuse wire to melt and break the circuit. Like a fuse, a circuit breaker acts as a switch that opens a circuit when the current in a circuit is too high. The current rating of a fuse or circuit breaker is selected to suit the current normally carried by each branch of a home circuit. The circuit breaker incorporated in a kitchen stove circuit for example would be triggered by a higher current than one connected to a room's lighting circuit.

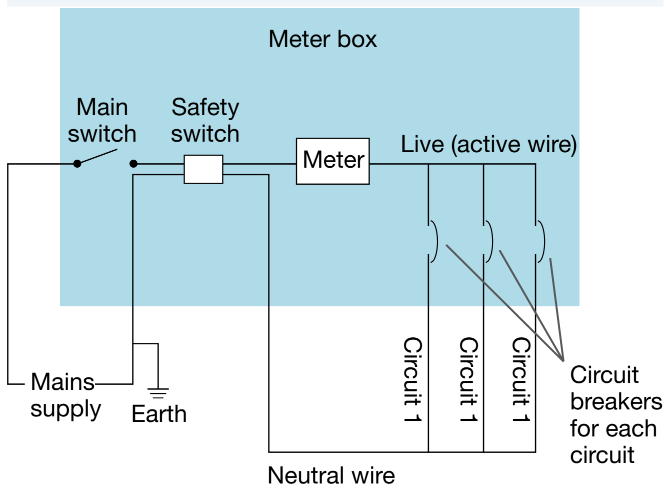
Circuit breakers and fuses open circuits before they can overheat, but they do not stop people from getting an electric shock. An electric shock occurs when an electric current flows through the body instead of the electric circuit. The effects vary depending on the size of the current. At low levels, a tingling sensation or muscular pain will be felt. In more severe cases breathing difficulties, burns and ultimately heart failure can occur. Being in contact with water can increase the current flowing through you by making your body a better conductor of electricity. For this reason it is not safe to use electrical appliances in wet conditions; that is, near taps, with wet hands or in the rain.

To minimise the risk of injury due to electric shock, every new home built in Australia is required to have a device called a **safety switch** installed, also known as a residual current device or RCD. Located in the meter box, a safety switch interrupts the current from the mains supply when there is danger of electric shock. It does this by monitoring the current entering and leaving a building. If the two values are not equal, it may be that current is leaking somewhere in the circuit, possibly due to faulty appliances or damaged wiring. As soon as this current leakage is detected, the safety switch stops the current flow by opening the circuit and preventing any likelihood of injury.

Schematic diagram of a circuit breaker. If the live wire carries an unusually higher current, the electromagnet's strength is increased, causing the electrical contact to be withdrawn to open the circuit. The spring keeps the contact apart until the circuit breaker is reset.



Schematic diagram of a meter box circuit



A safety switch, also called a residual current device

INVESTIGATION 3.7

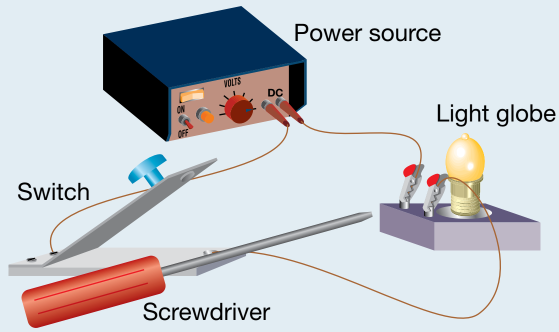
Modelling a fuse

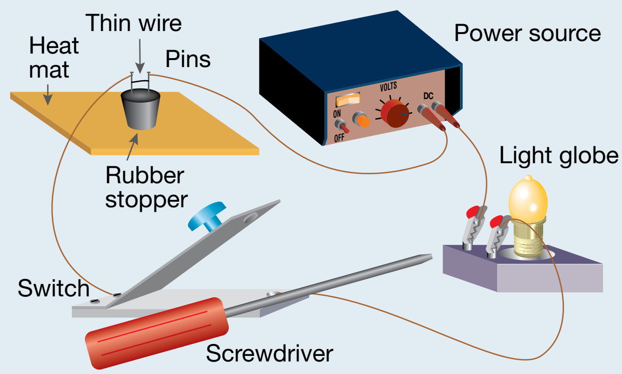
AIM: To demonstrate how an electric fuse works

You will need:

DC power source
4 wire leads with an alligator clip at one end
light globe and holder
switch
rubber stopper
heat mat
fine nichrome wire or strands of steel wool
screwdriver
2 metal pins

- Connect the circuit as shown on right. Set the voltage to 2 volts.
- Close the switch then carefully place a screwdriver across the alligator clips as shown in the diagram to bypass the light globe. Quickly observe any changes and remove the screwdriver again. Record your observations.
- Create a simple fuse and incorporate it into your circuit as shown below right.
- Place the screwdriver across the alligator clips as before to bypass the globe.
- Record any changes. If no changes are observed, increase the voltage and repeat the experiment.





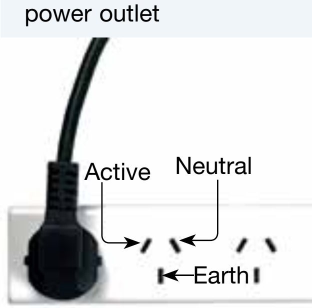
Discussion

1. What did you observe when a short circuit was first created using the screwdriver? Explain your results.
2. Explain how the fuse worked.
3. Outline the essential feature of a fuse wire.

3.3.5 The 3-pin plug

Power points in Australia have sockets designed to fit either 2-pin or 3-pin appliance plugs. When an electrical appliance is plugged in and switched on, alternating current flows through the appliance between the top two pins of the socket. Metal appliances normally have a 3-pin plug. This third pin is connected to the metal casing of the appliance. If a live wire should come into contact with the casing, due to damage to the wiring, current flows directly out of the earth wire to a metal pipe in the ground outside the home.

A three pin plug and power outlet



The earth wire outside a home

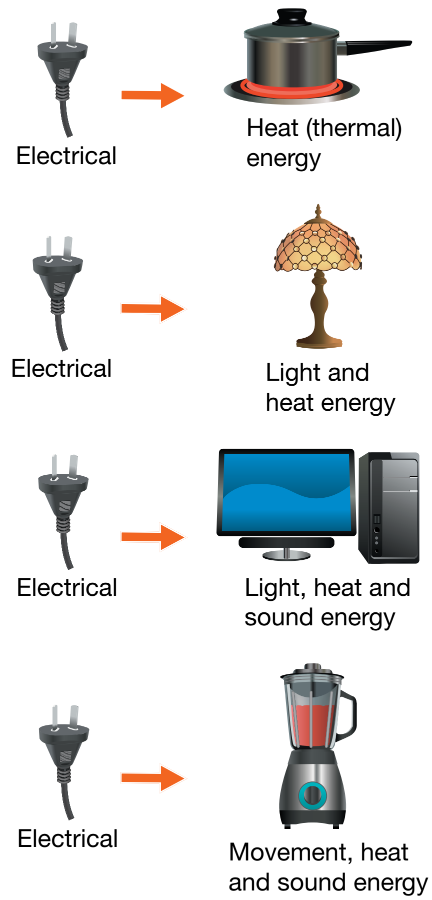
An earth wire prevents electric shock if you touch an electrical appliance with a short circuit.

This will prevent anyone coming in contact with the faulty metal appliance getting an electric shock. Appliances with 2 pin plugs means they are insulated instead of having an earth wire. This means they have a plastic external casing rather than a metal one and any external metal parts are carefully insulated from the internal wiring.

3.3.6 Electrical appliances — transforming electrical energy

Where would we be without electrical appliances? Our homes are full of them: in the kitchen you may have a toaster, blender, dishwasher, fridge, cooktop and oven. In the laundry you probably have a washing machine and clothes dryer. Not to mention the variety of personal communication and entertainment devices throughout the home. Each of these appliances transforms electric energy to other useful forms of energy.

> Electrical appliances transform electrical energy to other useful forms.



3.3.7 Electric motors

What do a hair dryer, a DVD player, a food processor, a clothes dryer and an electric drill all have in common? These appliances all contain an **electric motor**. An electric motor is a device that converts electrical energy into kinetic energy.

> An electric motor converts electrical energy into kinetic energy. This conversion can only take place because of the magnetic effects of an electric current.

3.3.8 How a DC electric motor works

The armature

When electric current flows through the **rotor coils** of the armature, a magnetic field is produced. The magnetic field produced by these coils interacts with the magnetic field of the **field magnets**. The repulsive and attractive forces acting on the rotor coils causes the armature to rotate.

The field magnets

The field magnets are permanent magnets located around the armature.

The brushes

These brushes are connected to the power supply and lightly touch the commutator as the armature turns. This allows current to travel through the rotor coils.

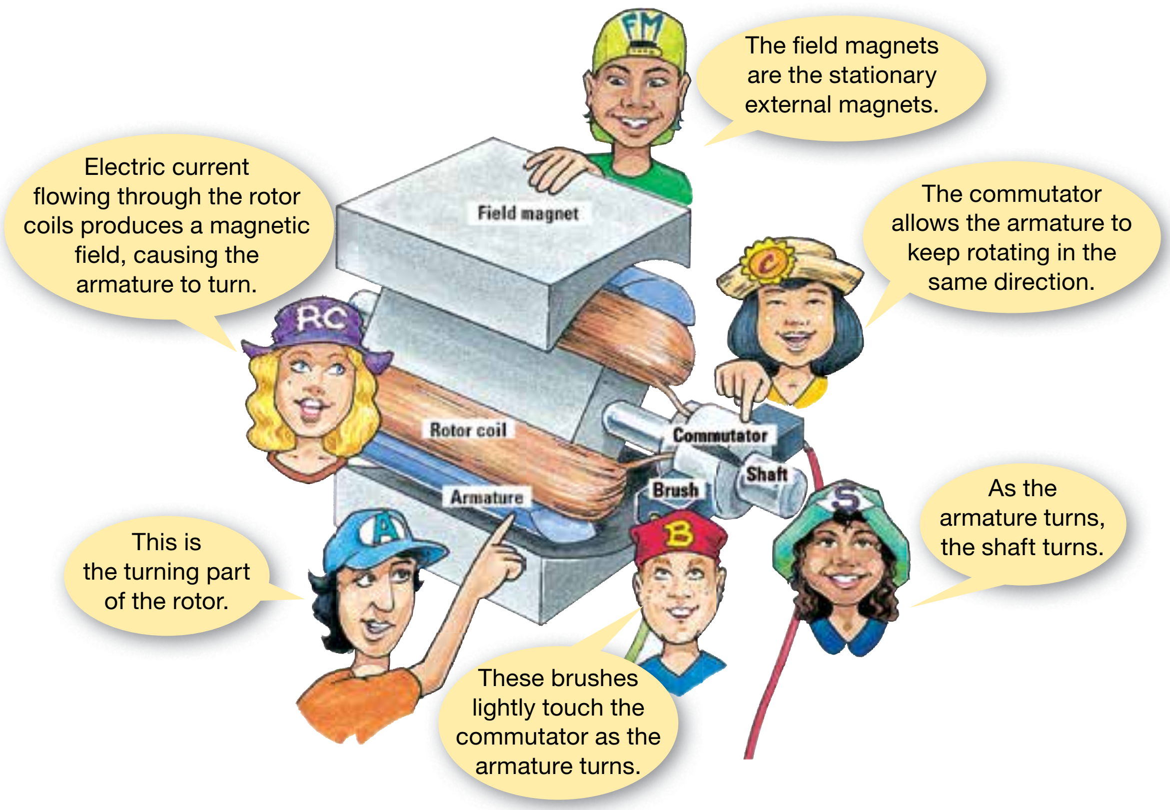
The shaft

This part of the motor is attached to the device the motor is turning, like a fan or gear wheel. As the armature turns, the shaft turns.

The commutator

As each rotor coil turns half a rotation to face the opposite field magnet, the force on it would change direction, turning it back the other way. The **commutator** consists of a split metal ring. As the armature turns, the commutator turns with it while the brushes remain still. When the armature has turned through 180 degrees, the opposite side of the commutator makes contact with the brush connected to the positive terminal of the power supply. This allows the armature to keep rotating in the same direction, rather than spinning first one way, then the other.

A simplified diagram of a DC electric motor



INVESTIGATION 3.8

A model motor

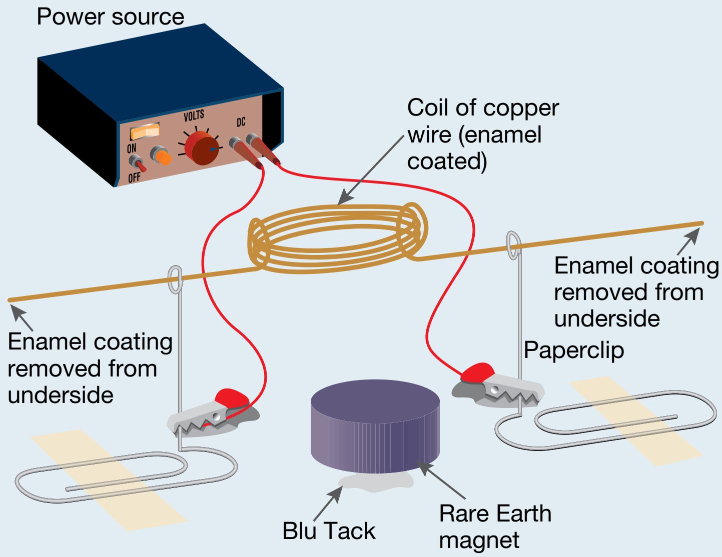
AIM: To construct an electric motor

You will need:

DC power source
2 large paperclips
sticky tape
Blu Tack
1 m of enamel-coated copper wire
a strong (rare Earth) magnet
large test tube
emery paper

- Wind the copper wire around a large test tube leaving a 3–4 cm length of straight wire at each end of the coil. Loop each end of the wire around each side of the coil to hold the coil together and extend the two ends of wire horizontally.
- Remove the enamel coating from the bottom side of each end of the wire using the emery paper.
- Bend the two paperclips as shown in the diagram and tape the base of each to the bench to create a stand to support the coil.

- Fix the rare Earth magnet to the bench using Blu Tack in a position directly below the coil.
- Connect wire leads to each paperclip stand, being careful to keep the alligator clips well away from the magnet to prevent them attracting.
- Connect the leads to a 6 V DC power source.
- Switch the power on. You may need to give the coil a gentle push to start it spinning.
- Record your observations.



Discussion

1. Outline the energy transformation taking place in this model motor.
2. Explain what causes the motion of the coil.
3. Identify the component of your model motor that acts as the:
   (a) rotor
   (b) brushes
   (c) field magnet
   (d) commutator.

3.3.9 Counting the cost

The power rating of an electrical appliance indicates how quickly electrical energy is used and converted to other forms of energy. The law of conservation of energy states that the energy input, in this case in the form of electrical energy, is equal to the energy output in an energy transformation. In electrical appliances, electrical energy is transformed to other forms. Some forms are useful, such as the light produced by an incandescent (filament) light globe, while other forms represent wasted energy such as the heat produced by these globes. Electrical power is measured in watts (W) and is equivalent to joules per second. A 75-W incandescent light globe uses 75 joules of energy per second and would be more costly to run than an 18-W compact fluorescent light which uses 18 joules/second.

Appliance	Typical power rating (W)
Fluorescent light	20
Notebook computer	20
Desktop computer	120
Television	200
Toaster	1000
Hair dryer	1500
Electric kettle	1700
Air conditioner (medium sized)	5000

The table at right provides the power rating of some common appliances.

The power rating can be used to determine the electrical energy used by an appliance as follows:

Electrical energy use (joules) =
electrical power (watts) × time in use (seconds)

For example, using a desktop computer for half an hour would use:

$120 \text{ W} \times 30 \text{ min} \times 60 \text{ s/min}$
$= 120 \text{ J/s} \times 1800 \text{ s}$
$= 216\,000$ joules
$= 216$ kilojoules of energy

An electricity meter located in your home's meter box monitors your energy usage in kilowatt-hours.

Electricity meters measure the number of kilowatt-hours of energy used in homes.

The joule is a very small unit of energy, so electricity suppliers charge us in units called kilowatt-hours (kWh). A kilowatt-hour is the energy used by a 1 kilowatt appliance for an hour. The power use of an appliance depends on the type of energy conversion it carries out. Low-power appliances include fluorescent lights and laptops and usually convert electrical energy to light and sound energy. High-power appliances such as electric kettles and toasters generally convert electrical energy to heat and cost more to run.

Electricity suppliers charge us for the amount of energy we consume in our homes.

Energy companies measure the amount of electrical energy used by a household in kilowatt-hours.

Every three months, the meter box is read so that the energy company knows how much electricity the customer has used.

Households are charged a fixed amount for every kilowatt-hour of electricity they use. This customer was charged 20.6 cents per kilowatt-hour.

Energy Used and Costs

METER ID –	THIS READING =	LAST READING ×	USAGE SPLIT ×	RATE =	COST
Single Energy Rate – Contract (12/01/17 – 11/04/17)					
	46851.0	45998.0	First 853.0 kWh	853.0*20.600c	$175.72
Electricity Service Availability Charge			91Days	48.000c/Day	$43.68
*based on 19.1781 kWh/billing day					
Total Electricity before GST 853.0 kWh $219.40					

INVESTIGATION 3.9

Comparing electrical appliances

AIM: To compare the power use and energy conversion in a range of electrical appliances and devices

You will need:

a range of electrical appliances and devices; e.g. radio, hair dryer, blender, laptop, fluorescent light, incandescent light, hot water kettle

- Examine each of the devices, preferably while they are operating. For each one record in a suitably designed table the:
  – type of energy input
  – useful energy output (there may be more than one)
  – wasted energy output (there may be more than one)
  – operating power in watts (this should be labelled on the device).

Discussion

1. Which appliance/device consumes:
   (a) the most power?
   (b) the least power?
2. Which device do you consider would be the:
   (a) most efficient, producing the least wasted energy?
   (b) least efficient, producing the most wasted energy?
3. Account for the higher operating power of some of the devices in terms of the type of energy transformation that takes place.

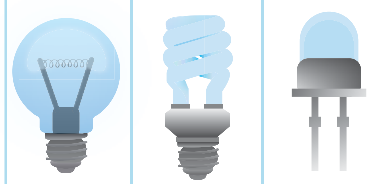
3.3.10 Energy efficient appliances

The light globes used for many years in Australian homes are called incandescent globes. In incandescent globes, electricity passes through a thin filament, generally made of tungsten metal, causing it to glow white hot. These are relatively inefficient devices for lighting as only 10% of the supplied electrical energy is converted to light; the rest is released as heat.

To encourage the use of more energy efficient lighting, the sale of incandescent light globes was phased out from 2010 and replaced by more energy efficient alternatives that produce at least 15 lumens per watt of electricity used. Lumens (lm) are a measure of light output. These energy efficient alternatives include compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) which convert closer to 70% of electricity energy to light.

CFLs and LEDS represent a technological advancement in lighting. CFLs consist of a coiled glass tube filled with argon gas and a small amount of mercury vapour. An electric current passes through the gas-filled tube, causing the mercury atoms to emit ultraviolet light, which in turn excites a fluorescent phosphor coating on the inside of the tube, producing the visible light. A CFL's ballast regulates the current when the electricity starts flowing.

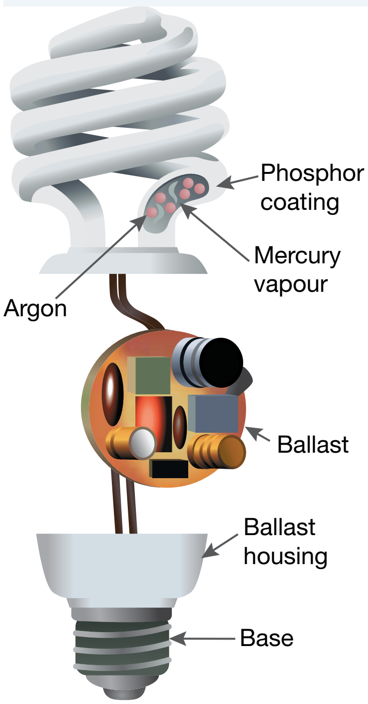
CFLs and LEDs are energy efficient alternatives for lighting.



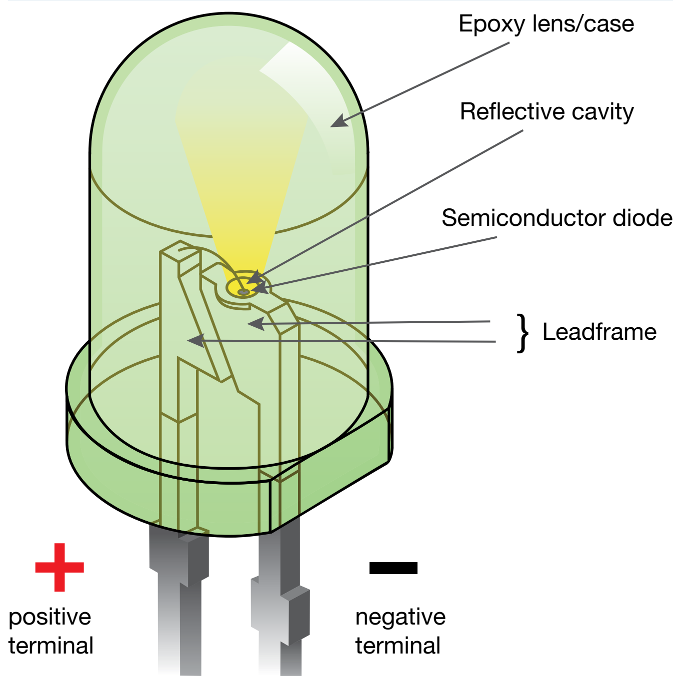
	Incandescent light bulbs	Compact fluorescent lamps (CFLs)	Light emitting diodes LEDs
Electrical power use equivalent to 60 W incandescent light bulb	60 watts	13–15 watts	6–8 watts
Electrical energy use per year based on 20 lights operating 8 hours per day	3506 kWh/yr	760 kWh/yr	350 kWh/yr
Approximate annual operating cost at 21 cents per kWh	$736	$160	$74

LEDs contain an electronic component called a semiconductor diode, similar to the miniature electrical components contained in an integrated circuit. When electricity flows through an LED, the electrical energy is converted to light energy very efficiently with minimal heat produced. One individual LED does not produce as much light as one CFL or one incandescent globe, so many small LEDs are often used together for lighting purposes.

The components of a CFL



The components of an LED



INVESTIGATION 3.10

Light globe efficiency

AIM: To compare the efficiency of an incandescent light with a CFL

You will need:

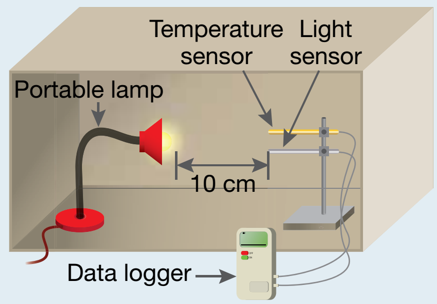
cardboard box
data logger
temperature sensor
light sensor (optional)
portable lamp
an incandescent light and CFL of equivalent light output as follows:

Incandescent light	CFL
40 watts	9–13 watts
60 watts	13–15 watts
75 watts	18–25 watts
100 watts	23–30 watts

- Insert the incandescent globe into the portable lamp.

CAUTION: Ensure that the lamp is not connected to the power outlet while light globes are inserted or removed.

- Connect the temperature sensor and light sensor (if available) to the data logger.
- Position two sensors 10 cm away from the lamp within the cardboard box and record the temperature and light intensity each minute over a 10-minute period.
- Repeat the experiment with a CFL.



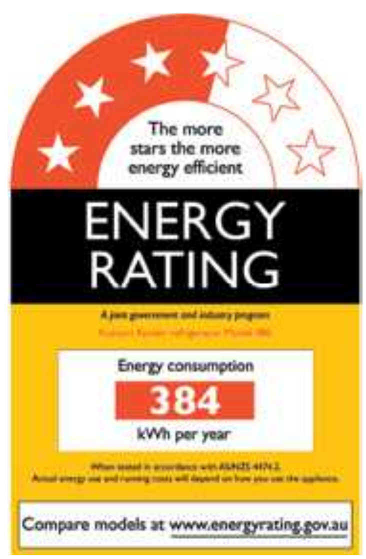
Discussion

1. Compare the temperature change due to the incandescent light and the CFL.
2. Compare the light intensity of the incandescent light and the CFL.
3. Which light globe is the most energy efficient? Explain in terms of the data collected.
4. Calculate the:
   (a) energy use for each globe in kWh if each was run for 8 hours
   (b) annual cost of running each lamp 8 hours per day assuming a tariff of 21c per KWh.

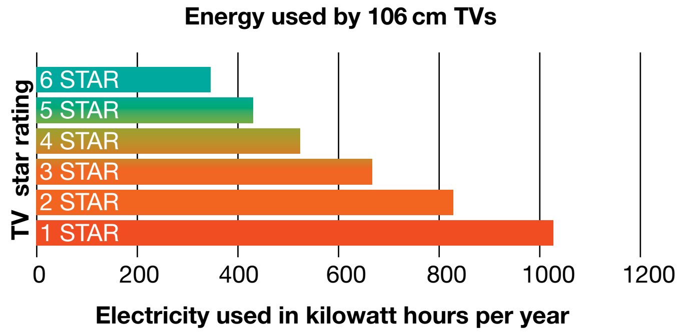
3.3.11 Rating energy efficiency

In Australia it is mandatory for electrical appliances such as refrigerators, washing machines, dishwashers, air conditioners and televisions to carry an energy rating label. The label provides each appliance with a star rating: the greater the number of stars, the higher the energy efficiency of the appliance, compared to others of a similar size or capacity. This rating is based on the appliances' estimated annual energy use (measured in kilowatt hours) calculated from its power consumption and information about the typical use of the appliance in the home.

The rating system enables consumers to compare the energy efficiency of appliances and provides incentive for manufacturers to improve the energy performance of their products through research and development.



The higher the energy efficiency rating of an appliance like a TV, the less electrical energy consumed per year.



INVESTIGATION 3.11

Investigating energy efficiency

AIM: To calculate the energy efficiency of an electrical appliance

You will need:

electric kettle
100 mL measuring cylinder
data logger and temperature probe
stopwatch

- Use the measuring cylinder to measure and pour 500 mL of water into the electric kettle.
- Place the tip of the temperature probe into the kettle and record the initial temperature of the water.
- Remove the temperature probe then switch on the kettle and heat the water for 60 seconds.
- Insert the temperature probe again to record the new water temperature.
- Calculate the temperature rise over the 60-second period and record your data.
- Refer to the label on the kettle to identify and record the power use of the kettle.

Discussion

1. Calculate the input of electrical energy to the kettle over the 60-second period:
   Electrical energy input (J) = Power (watts) × operating time (s)
2. Calculate the output of heat energy gained by the water in the kettle as follows:
   Heat energy output (J) = volume of water (mL) × 4.2 × temperature rise (°C)
3. Calculate the efficiency of the kettle as follows:

$$\text{Efficiency}(\%) = \frac{\text{Heat energy output}}{\text{Electrical energy input}} \times 100$$

4. Explain why the efficiency of the kettle is well below 100% in terms of transformation of electrical energy and the transfer of heat energy generated.

3.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Compare** AC and DC electricity.
2. **Explain** why devices like electronic games and computer printers have transformers attached to their power cords.

3. **Explain** why circuit breakers and fuses are an essential safety feature of home electrical circuits.
4. **Identify** the energy transformation taking place in:
   (a) an electric stove
   (b) a hair dryer.
5. **Explain** why incandescent lights have been phased out in preference for compact fluorescent lights and LEDs.

Think

6. What types of home appliances have the greater power use? **Explain** why.
7. **Explain** how a fuse or circuit breaker works.
8. What type of appliances require an earth wire and a three pin plug? Why?
9. **Identify** three devices that contain an electric motor.

Calculate

10. How much electrical energy (in joules) is transformed by each of the following appliances:
    (a) an 18 watt light globe in 6 hours?
    (b) a 2000 watt toaster used to toast a slice of bread for 2 minutes?
11. How much would it cost to operate each of the following appliances if the cost of electrical energy is 21 cents per kilowatt-hour? (Remember, 1 kW = 1000 W.)
    (a) A 5000 watt air conditioner for 30 minutes
    (b) A 1500 watt electric blanket for 8 hours
12. Assuming that the cost of electrical energy is 21 cents per kilowatt-hour, use the data in the table below to **calculate** how much it costs to:
    (a) use a medium sized air conditioner to cool a room for four hours
    (b) watch television for two hours every day for a week.

Appliance	Typical power rating (W)
Fluorescent light	20
Notebook computer	20
Desktop computer	120
Television	200
Toaster	1000
Hair dryer	1500
Electric kettle	1700
Air conditioner (medium sized)	5000

3.4 Meeting our future electricity needs

Science as a human endeavour

3.4.1 The electronics age

Over the past decade there has been huge growth in the use of electronic devices like computers (both laptops and desktops), MP3 players, DVD technology, mobile phones and personal organisers.

Electronics is one of the fastest growing industries in Australia and world wide. This is partly because we are becoming more dependent on computers and electronic communication involving the internet and mobile phones.

3.4.2 Integrated circuits

Electronic devices rely on complex electrical circuits that are almost too small to see. In these devices **integrated circuits** that contain thousands of miniature electronic components are etched onto **chips**; thin pieces of the semiconductor silicon.

A desktop computer's integrated circuit

Modern communication devices rely on integrated circuits.

The first silicon chip was developed in 1958 and, by 1965, most chips could hold about 30 electronic components. In 1975, a similar sized chip could hold about 30 000 components, allowing the production of desktop computers with increasingly sophisticated processing capabilities. New methods of producing chips with smaller and more complex circuits has meant that chips may now contain millions of electronic components.

The manufacture of silicon chips

Silicon chips make up only a very small part of the circuit boards and memory cards in electronic devices. The chips are usually no larger than the fingernail on your little finger. They are very delicate and can be damaged by vibrations, moisture, heat, magnets and light. The silicon chips are glued to a plastic case and linked to metal pins by thin copper or aluminium wiring.

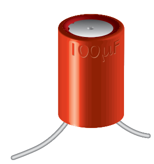
A close-up of silicon chips

A silicon chip that is able to store information, process it and control other electric circuits is called a **microprocessor**. Since their development in 1971, microprocessors have been used in calculators and computers. As microprocessors became less expensive and smaller, they began to be used in household appliances like microwave ovens, televisions and washing machines. The inclusion of microprocessors in these appliances makes them 'programmable' and able to perform tasks with little human effort. Microprocessors are used in automated equipment in many industries including manufacturing, mineral processing and the car industry. They are also used in cars, phones, cameras, watches and many other devices that need to store and process information.

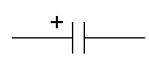
3.4.3 Electronic building blocks

Apart from resistors, the most common electronic components in circuits are capacitors, diodes and transistors.

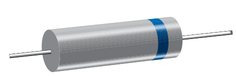
Capacitors store electric charge for a short time before allowing it to flow to other parts of a circuit. The amount of charge that can be stored per volt across a capacitor is called its capacitance. Capacitance is measured in units of farad (F) or microfarad (μF).



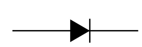
Capacitor



Symbol

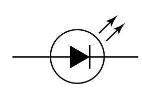


Silicon diode



Symbol

Light-emitting diode (LED)



Symbol

Diodes allow electric current to travel through them in only one direction. They look like small resistors but have a single band at one end. This end of the diode is the negative end and should be connected closer to the negative terminal of the power supply.

LEDs are often used as indicator lights in electrical appliances. An arrangement of seven LEDs can be used in devices like watches, clocks, calculators and digital meters to display any number between 0 and 9. The display circuit is designed so that the LEDs light up in different combinations.

Liquid crystals displays (LCD) are often used instead of LEDs for the same purpose. Small voltages cause the molecules in liquid crystals to rearrange themselves, changing the colour of the crystals.

Transistors act like switches, changing the size or direction of electric current as a result of very small changes in the voltage across them. This makes them ideal for use in devices that amplify sound. However, they have many other uses and most electronic devices contain chips that hold many microscopic transistors.

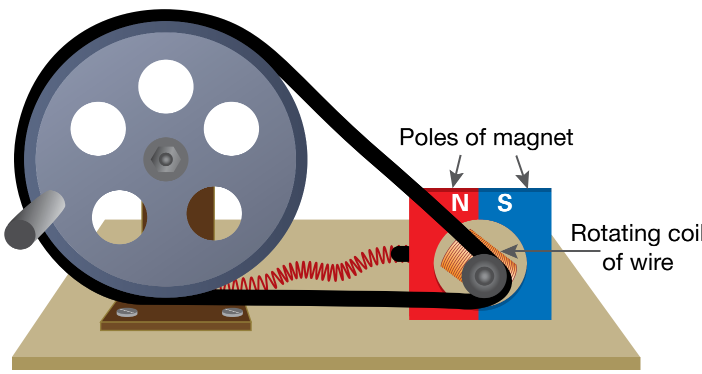
3.4.4 Generating electricity

The electricity used to charge your mobile phone and laptop and to power other electrical appliances common in society today is the result of an energy transformation that takes place in power stations, often thousands of kilometres from the consumer. In a power station fossil fuels such as coal are burnt, and the chemical energy released is used to boil water that generates steam, which at high pressure has sufficient kinetic energy to turn the blades of huge turbines. The turbines then spin industrial generators, creating AC electricity. Cold water is pumped through a condenser to convert the steam returning from the turbine back to water. This water, which is still hot, is pumped into a cooling tower where some steam escapes into the atmosphere.

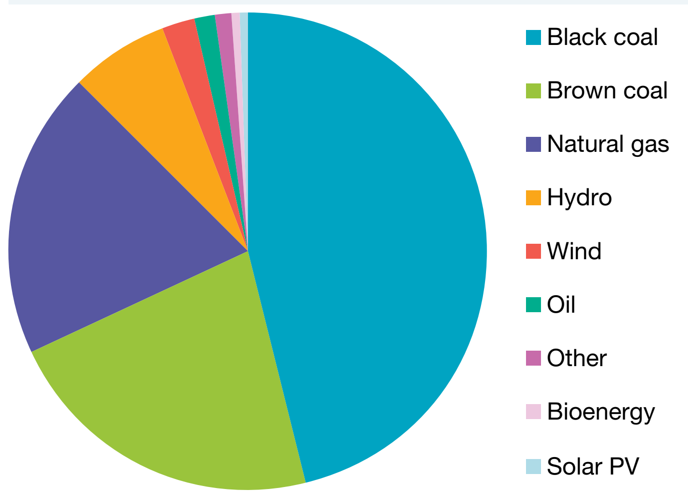
Generators work on the principle that a coil of wire moving in a magnetic field creates a current of electricity. This can be demonstrated with a simple hand generator.

Coal fired power plants account for over 75% of Australia's electricity production and natural gas a further 15%. These fossil fuels are examples of non-renewable energy resources. Australia relies so heavily on coal in particular because coal is a relatively cheap energy source in Australia and coal reserves are relatively abundant along the eastern seaboard, where the majority of electricity is generated and consumed.

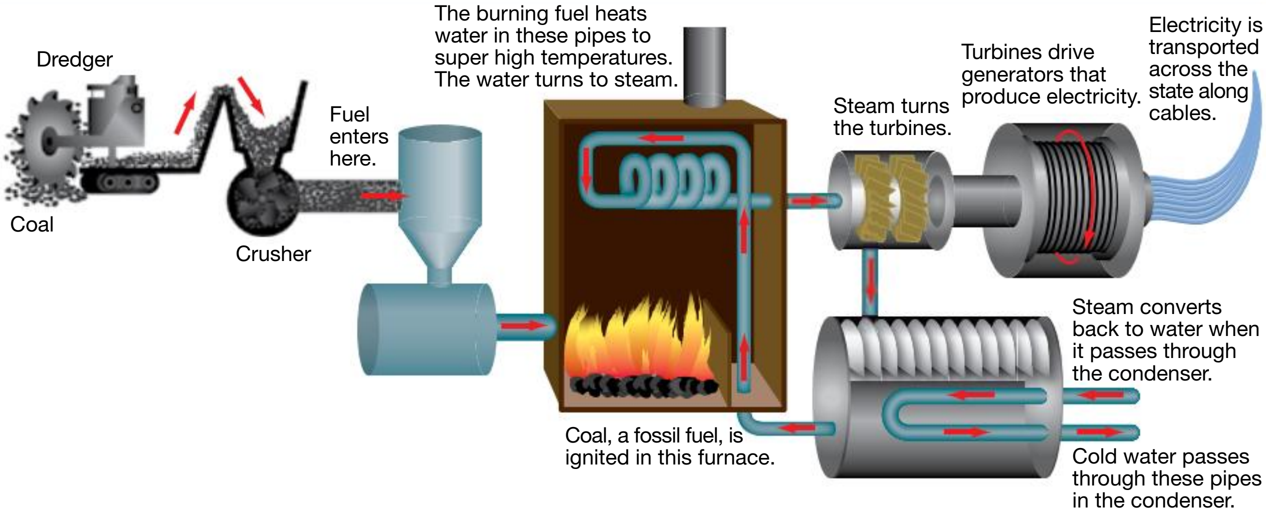
A model generator demonstrates that motion between a coil of wire and a magnetic field creates a current in the coil.



Energy sources used in electricity generation in Australia. Fossil fuels like coal, gas and oil account for over 90%.



The chemical energy contained in fossil fuels like coal is used to generate electricity in power stations.



INVESTIGATION 3.12

Electricity generation

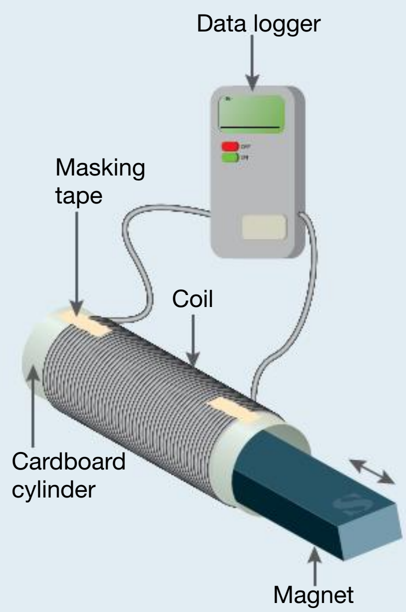
AIM: To investigate the principles of electricity generation

You will need:

solenoid or coil of laminated wire wound around a cardboard cylinder
micro-ammeter
2 wire leads
2 bar magnets
rubber band
handheld generator
data logger and voltage sensor

Part A: Current produced by a solenoid

- Connect the solenoid to the micro-ammeter.
- Move the north pole of the bar magnet quickly into an end of the solenoid and record the current produced — both its magnitude and whether it is positive or negative.
- Remove the bar magnet quickly and record the current again.
- Carry out each of the following investigations and record your observations for each of the following:
  (a) the effect of moving the magnet in and out more rapidly
  (b) whether holding the bar magnet stationary in the solenoid generates a current
  (c) the effect of increasing the strength of the magnet — this can be done by attaching the north poles of two bar magnets together using a rubber band.



Part B: Voltage produced by a hand generator

- Connect the voltage sensor to the data logger and connect the leads of the voltage sensor to the terminals of the hand generator.
- Record the voltage produced as the handle of the generator is turned. You may be able to generate AC or DC or both. Monitor the effect of spinning the generator faster and slower.

Discussion

1. What magnitude of current is generated by moving the bar magnet in and out of the solenoid? Don't forget to include scientific units.

2. Is the direction of the current affected by the direction of the moving magnet? Are you generating AC or DC electricity? Explain.
3. Is motion required for a current to be generated? Refer to your observations.
4. Do the speed of the magnet and the strength of the magnet affect the size of the current? Discuss.
5. Did your generator create AC or DC electricity? How do you know?
6. What energy transformation is taking place in the hand generator? What takes the place of your hand in the turbine of a coal power station?
7. How does the speed of the generator affect the voltage produced? Are there parallels with the activity examining the current in a solenoid?

3.4.5 Non-renewables versus renewables

Our dependence on coal and gas to generate electricity brings with it certain responsibilities — for government, industry, power companies and individuals. The first step is to be aware of the problems caused by using fossil fuels and the alternative methods of generating electricity.

One of the products of the combustion of fossil fuels in power stations is carbon dioxide. Increased levels of carbon dioxide in the atmosphere is contributing to global warming which could have significant consequences for the climate and the biosphere in the years ahead. In addition, some of the chemicals in the coal burnt in power stations produce gases like sulfur dioxide and various nitrogen oxides, causing **air pollution**. These gases may also dissolve in water vapour in the atmosphere, creating acid rain. Acid rain speeds up the weathering of rocks, eats into building materials, and threatens plants and other living things that depend on the plants.

However, there is another form of pollution that is not so obvious. During electricity generation heat energy is transferred to the surroundings, increasing the temperature of the air and waterways. This increase in the temperature of the environment is known as **thermal pollution**. Thermal pollution of lakes is a serious problem as the increased temperature (even one or two degrees Celsius) decreases the amount of oxygen dissolved in the water, threatening organisms that live in the water and within the ecosystem.

3.4.6 Looking for alternatives

The demand for electrical energy is increasing, both in Australia and worldwide and so the supply of **fossil fuels** like coal, natural gas and oil used in power stations is diminishing.

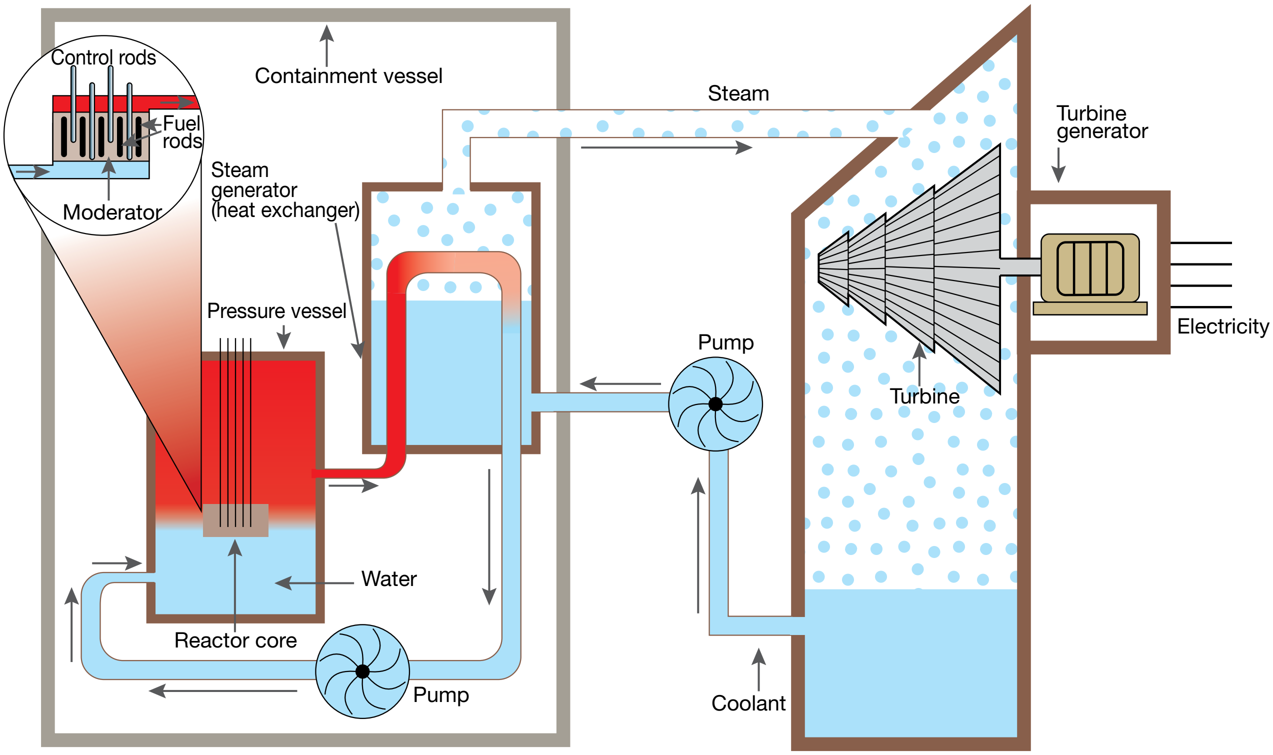
	Known reserves based on current rates of production and use (years)	
Fossil fuel	Australasia	Global
Coal	53	112
Oil	14	54
Natural gas	35	64

The air, water and thermal pollution caused by burning fossil fuels to generate electricity is not acceptable to many people. So even though the cost of electricity production using fossil fuels is low by comparison with newer non-renewable technologies, many governments throughout the world are supporting research and the development of alternative methods for electricity generation.

3.4.7 Nuclear energy

Nuclear power stations use energy released from the nuclear fission of radioisotopes like uranium to drive turbines that generate electricity in the same way that fossil fuel power plants operate. Like fossil fuels, uranium is a non-renewable resource, but because nuclear power plants do not rely on the combustion of fossil fuels to generate electricity, greenhouse gases are not emitted. The critics of nuclear power object to this alternative because the nuclear waste produced must be stored for many years and because of the risk of nuclear accidents.

In a nuclear power plant fuel rods, generally of uranium oxide, are placed within the reactor core. The rods are bombarded with neutrons to initiate a fission reaction that liberates huge quantities of heat energy and further neutrons. A moderator within the core, usually water or graphite, slows the neutrons released from fission so that they cause more fission. Control rods, made of neutron-absorbing material such as boron, are inserted or withdrawn from the core to control the rate of reaction. A liquid or gas is circulated through the core to transfer the heat produced to the steam generator from which high pressure steam is used to drive a turbine and generate electricity.

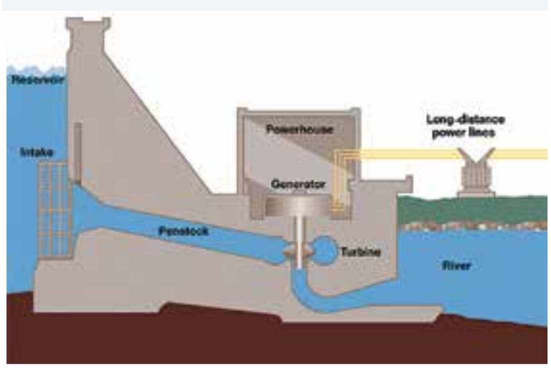


While Australia is yet to utilise this technology for generating electricity, there are 439 nuclear reactors operating in 30 countries that account for around 17 per cent of world electricity production. Nuclear power accounts for a large proportion of the electricity supply in many parts of Europe, Japan and the USA.

3.4.8 Hydro-electricity

A small proportion of Australia's electricity is generated by hydro-electric power plants, a renewable source of energy. As water stored in a dam at high elevation falls through pipes, it gains kinetic energy. This kinetic energy is used to turn turbines that generate electricity. This does not involve combustion of a fossil fuel and so does not generate greenhouse gases. A disadvantage of hydro-electricity is that it involves damming river systems and thus alters ecosystems.

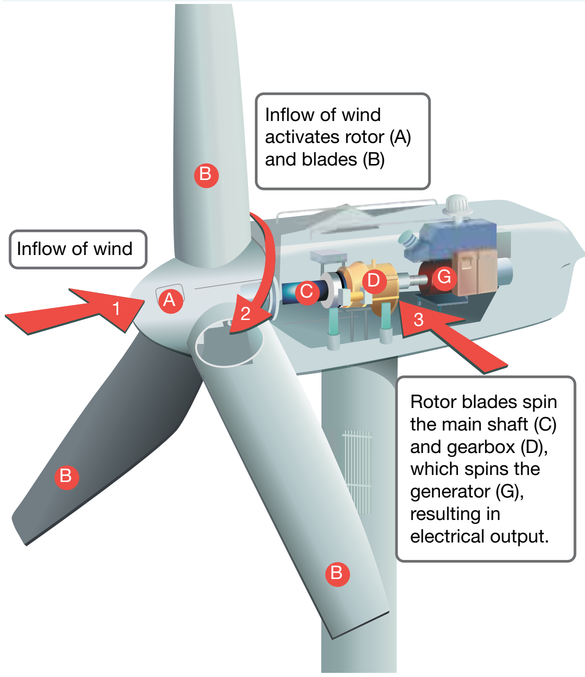
Turbines in a hydro-electric power plant are driven by the kinetic energy of water.



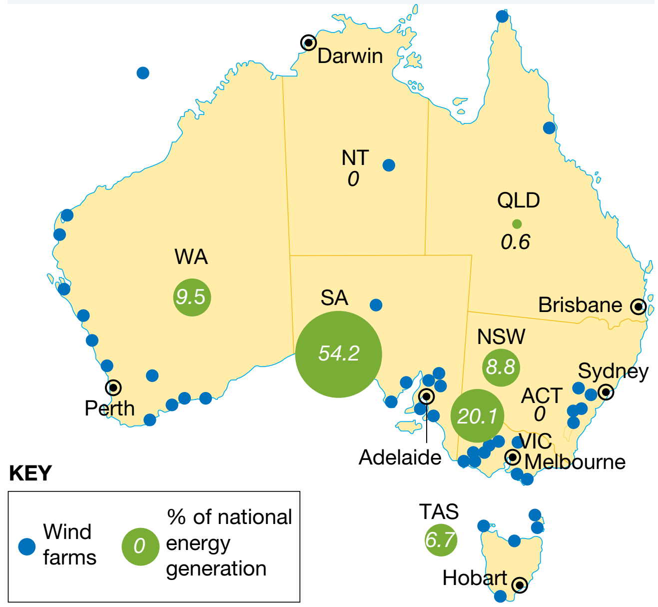
3.4.9 Wind energy

Wind 'farms' dotted with wind turbines can be found in many countries throughout the world, including Australia. One of Australia's largest wind farms is located near Ararat in Victoria and consists of 35 towers generating 53 000 kilowatts of electricity. In comparison, one of New South Wales' smallest coal-fired power stations at Redbank produces 150 000 kilowatts of electricity while the largest, Baywater in the Hunter Valley, generates almost 20 times more. In 2011, 57 wind farms in Australia provided 1188 wind turbines generating sufficient electricity to power 900 000 homes or 2.7% of our nation's electricity needs.

How a wind turbine works



Wind farms with percentage of national energy generation



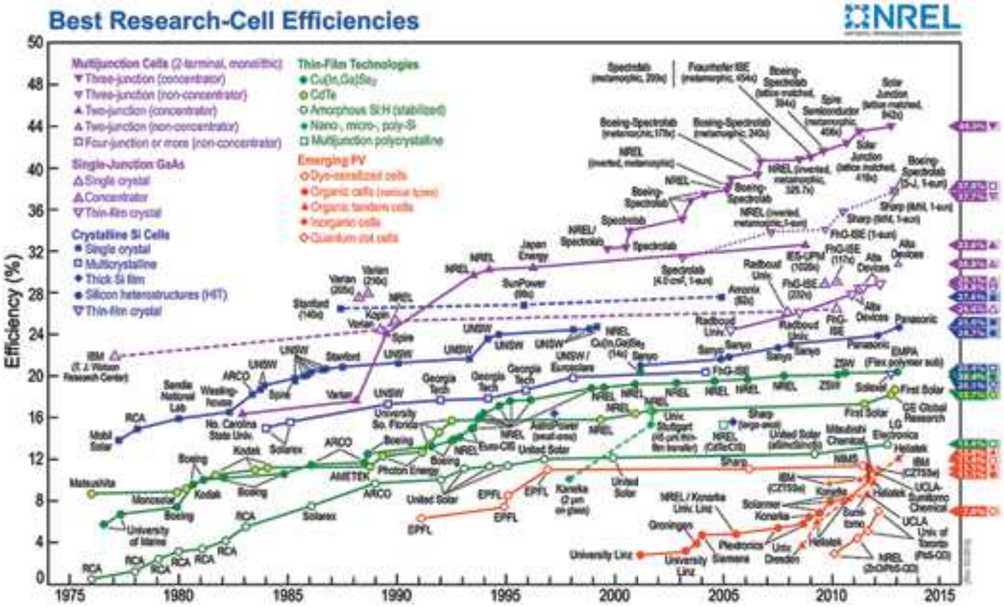
3.4.10 Solar energy

Electricity can be generated by solar energy in two different ways. **Photovoltaic cells**, often called solar cells, like those on the house illustrated below right, consist of silicon wafers, with impurities of other elements added like boron and phosphorus. When sunlight falls on the cells, electrons are emitted from the wafers creating an electric current. The most advanced solar cells convert over 40% of incident solar radiation to electrical energy. Scientists and engineers worldwide are endeavouring to develop more efficient photovoltaic cells.

Another solar technology, solar thermal power stations, uses arrays of curved mirrors to reflect sunlight onto tubes filled with oil. The hot oil is used to heat water to form steam which drives turbines just like those in coal-fired power stations.

Six to eight solar roof panels generate approximately 2300 KWh of electricity per year.

Competition between research institutions worldwide has led to new breakthroughs in photovoltaic technology and has resulted in greatly increased efficiency in the more advanced solar cells.



3.4.11 Biomass

Biomass is an energy source that involves burning waste vegetation or burning methane, the biogas produced by the breakdown of organic matter to drive small generators. In Australia biomass accounts for 15% of the electricity generated from renewable sources. In Queensland and northern New South Wales the waste vegetation from sugar production is used in commercial power generation. Small amounts of energy are also produced by burning wood waste at some timber mills.

Methane-powered generators at rubbish tips such as Woodlawn near Goulburn have taken in over 2.2 million tonnes of waste from the Sydney metropolitan area and Goulburn surrounds, producing up to 3000 KWh of green electricity.

Woodlawn waste complex and its biogas generator. Woodlawn is a worked out copper, lead and zinc mine and as a landfill site has capacity for 70 years of Sydney's waste.

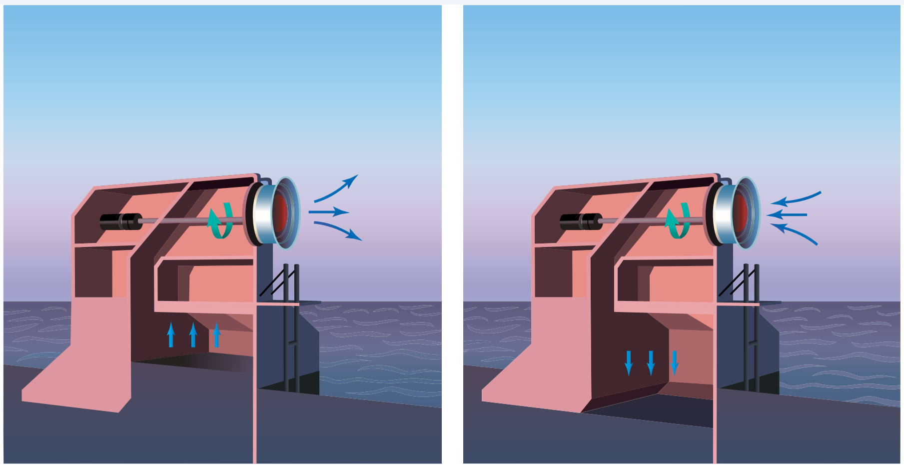
3.4.12 Ocean energy

Electricity can be generated using a range of ocean energy sources including tides, waves, marine currents, thermal layering and salt gradients. Only two of these sources are being investigated for development in Australia — tides and waves.

Tidal power stations harness energy from the rise and fall of tides and are currently being used in France, Russia and China. Turbines with reversible blades are placed at the entrance to a bay in areas with extremely high and low tides. Water moving in and out of the bay turns the turbines to generate electricity. A tidal range of at least 5 m is considered necessary for large-scale installations. Several areas were identified as suitable in the Kimberley region on the northwest coast of Western Australia.

Wave energy systems do not make use of waves as such, but rather the swell that occurs in deeper water or can be captured by coastal installations. Wave energy, for example, is being used to generate electricity in Norway. The waves flow into a narrow channel on the coast, where they are funnelled towards turbines. CSIRO studies show that waves off Tasmania's west coast have three times as much energy as those in Norway. One wave energy technology is being trialled off the coast of South Australia.

Electricity generation using wave energy is being developed in Port Macdonnell off the coast of South Australia. In this system, as waves rise (in the diagram on the left) and fall (in the diagram on the right) within a water column, it acts like a piston, driving a column of air ahead of it and through the turbine. The plant is expected to generate 1000 kilowatts of electrical power.



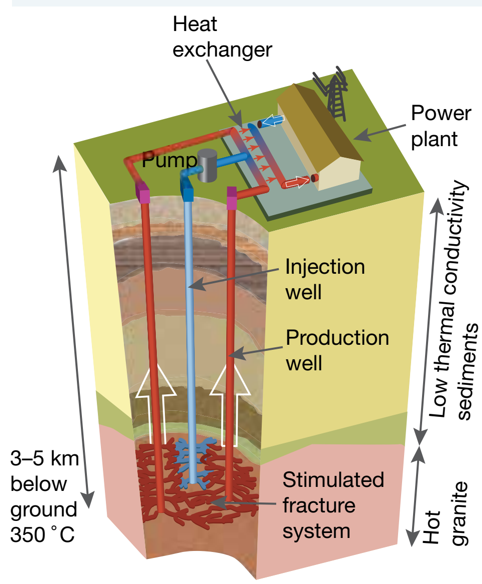
3.4.13 Geothermal energy

Heat energy trapped within the Earth's crust can be used to turn water into steam and drive turbines in Z power stations. Volcanically active regions of New Zealand have been tapped as a source of geothermal energy for electricity generation since the late 1950s and currently provide 7% of New Zealand's total electricity generation.

Hot fractured rock (HFR), normally granite, can be found at temperatures of over 250 °C at depths of 3 to 5 km. This represents an enormous energy resource that can be used to generate high-pressure steam to drive turbines in electricity generation. Preliminary work by Geoscience Australia suggests a potential HFR resource equivalent to 20 000 years of Australia's energy use at 2005 levels.

To develop this resource, boreholes need to be drilled into the HFR to allow the injection of water, which passes through fractures in the rock and returns to the surface as steam. Success primarily depends on the ability to drill deep into hot hard rock. Current drilling technology limits geothermal extraction to 5 km — at this depth sufficiently high temperatures to make the process

Geothermal energy from hot rocks involves circulating water via boreholes. The water returns to the surface super-heated then passes through a heat exchanger. Steam produced by the heat exchanger is used to generate electricity in a conventional steam turbine.



economically feasible occur only in 'hot spots' of above average temperature. Future development of drilling and extraction technologies is expected to expand the available geothermal resources.

INVESTIGATION 3.13

Solar cells

AIM: To investigate the performance of a solar cell under different lighting conditions

You will need:

a solar cell
a milli-ammeter or milli-voltmeter
wire leads

- Investigate the performance of the solar cell under different light conditions. You may like to try artificial lighting in the classroom, a dim area within the room, bright sunlight and outdoor shade.
- Record the current or voltage produced.

Discussion

1. Under which conditions was the greatest current/voltage produced?
2. Under which conditions was the least current/voltage produced?
3. Bright artificial light creates a similar current and voltage as bright sunlight. Do you agree? Explain why.

3.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** three household devices that utilise computer chips and integrated circuits and **outline** the use of each.
2. **Identify** an element incorporated in computer chips and **identify** a metal often used in the wiring of those chips.
3. Copy and complete the table below.

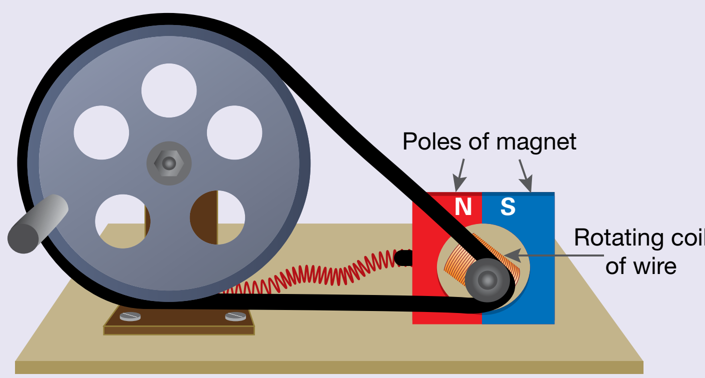
Electronic components

Component	Circuit symbol	Function
Capacitor		
Diode		
Transistor		

4. **Identify** the role of each of the following in a nuclear reactor:
   (a) moderator
   (b) control rods.

Think

5. **Identify** the role of the components of the generator labelled at right.
6. Use a table to list each of the following energy sources as renewable or non-renewable:
   (a) nuclear
   (b) hydro
   (c) coal



(d) wind
(e) biomass
(f) solar
(g) geothermal
(h) ocean energy
(i) natural gas

Think

7. How does photovoltaic (solar) energy technology differ to other forms of energy sources in the generation of electricity?

Analyse

8. Refer to the figure Wind farms with percentage of national energy generation. Which state in Australia satisfies the most of its electricity needs using wind power and which uses the least? **Explain** why this might be the case.
9. (a) Use the data contained in the table below to plot a line graph of the amount of energy produced using renewable energy sources in Australia from 2004–05 to 2009–10. A terawatt hour (TWh) is 10^{12} watt hours
(b) Which renewable energy source has increased in use the most over the five year period?

Australian electricity generation by fuel

	2004–05 TWh	2005–06 TWh	2006–07 TWh	2007–08 TWh	2008–09 TWh
Thermal					
Black coal	130.0	131.0	138.7	141.7	143.2
Brown coal	61.1	61.6	57.2	55.7	56.9
Oil	1.9	2.4	2.1	2.7	2.6
Gas	32.3	30.8	32.0	37.7	39.1
Total thermal	225.3	225.8	230.1	237.8	241.8
Renewables					
Hydro	15.3	15.7	14.3	11.9	12.3
Wind	0.9	1.7	2.6	3.1	3.8
Solar	0.1	0.1	0.1	0.2	0.3
Biomass	1.1	1.1	1.1	1.2	1.5
Biogas	0.8	0.9	0.9	1.0	1.3
Total renewables	18.1	19.5	19.0	17.4	19.2

Source: ABARES.

10. The table on the next page energy consumption by various industries in Australia over time. A petajoule (PJ) is equivalent to 10^{15} Joules.
Which industry has increased its electricity use the most as a percentage over the time period? **Account for** this increase.

Energy consumption in Australia by industry

	1974–75 PJ	1979–80 PJ	1989–90 PJ	1999–00 PJ	2008–09 PJ
Agriculture	39	47	55	72	95
Mining	65	81	160	273	429
Manufacturing	928	965	1067	1192	1257
Electricity generation	540	743	1066	1427	1744

Investigate

11. **Investigate** the generation of electricity by hydro-electric power stations in Australia. Include information on their location, history and the process of electricity generation. Present your research as an educational tourist brochure.
12. Coal seam gas is a controversial source of energy and its mining and use are currently being explored in Australia. What is coal seam gas and why do many sectors of society oppose it?
13. Survey your friends and family to develop a list of at least 20 strategies to cut your electricity use and so reduce your power bills. Use the **ABC environment** weblink in the Resources tab to compare your list with the list online.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: ABC environment

3.5 Project: Go-Go Gadget online shop

learnon

3.5.1 Go-Go Gadget online shop

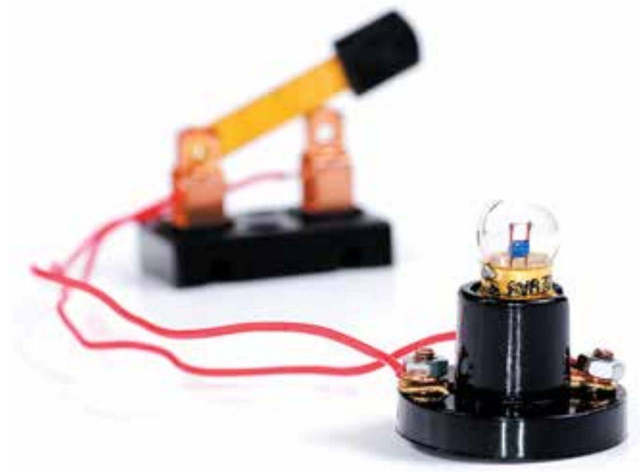
Scenario

We use the term *technology* to describe the application of science to develop devices, machines and techniques to make some aspect of our lives easier. Televisions, satellites and the internet are all pretty obvious examples of technology, but small devices such as the automatic cat-flap and the humble vegetable peeler are also forms of technology. Small or specialised pieces of technology such as these are often referred to as *gadgets*. Every year, patents for thousands of such gadgets are issued to inventors. Some of them, like the NavMan, are immediate successes, while others — for example, a combination shoe-polisher and toothpick — don't make it into mass production. So what happens if you need a device to do a particular job but no-one has ever made one?

This is just what you and your partners were thinking when you decided to open the Go-Go Gadget online shop. Once established, clients would browse designs for gadgets that you have already developed or ask you to design something new for them that will do the job they need done. Maybe the client wants a hamster wheel that can drive a coffee-grinder or a signalling device that will tell a cat-owner whether their cat has come inside through the cat-flap or is still outside. They just tell you what they need and you design it for them! You then ship them the design, the parts they need to assemble it and an instruction brochure.

To get the business started, you decide to take out a business loan with the bank. The bank manager is intrigued with the idea but wants some assurance that you know what you are doing before they hand over the money.

Your task



As part of your presentation to the bank, you and your business partners are to develop a design for one of the following clients.

- Taylor wants a snooping-parent device that will warn her when one of her parents is coming up the hallway that leads to her bedroom. This device will give her a silent signal so she has time to turn off her computer and open her homework books before they open the door and catch her playing computer games or surfing the net instead of working.
- Heisenberg has an office on the top floor of his house. His cat, Schrödinger, can enter the house through a cat-flap in the door downstairs. When Heisenberg is locking up the house when going out or to bed, it would save a lot of time if he could know whether the cat is already inside the house. He needs a device that is connected to the cat-flap that sends a signal to Heisenberg upstairs indicating whether the cat has come in or gone out the cat-flap.
- Felicity often works until late at night and doesn't get time to exercise her dog by taking her out for a walk. She can use her computer at work to turn on switches in her apartment, and wants a device that will allow her to exercise her dog by remote control without the dog leaving the apartment.

You will then create the following to submit to the bank in support of your loan application.

1. A brief overview (approximately 300 words) of why there is a market for the services of your online shop. To support your argument, you should include references to gadgets that have been successfully developed.
2. A brochure for the gadget you have designed that includes:
   - a diagram of your design
   - a list of parts that are included in the package sent with the brochure
   - instructions on assembly/installation of the gadget
   - a troubleshooting guide to solve problems.

3.6 Review

3.6.1 Electric circuits

- design, **construct** and draw circuits containing a number of components **3.2**
- **define** the terms 'current', 'voltage' and 'resistance' **3.2**
- **identify** the symbols for current, voltage and resistance and their units of measurement **3.2**
- **describe** voltage, resistance and current using analogies **3.2**

- **outline** how current and voltage can be measured in circuits 3.2
- **describe** the relationship between voltage, resistance and current 3.2
- solve problems using Ohm's Law 3.2
- **compare** the characteristics and applications of series and parallel circuits 3.2

3.6.2 Electricity at home

- **compare** AC and DC electricity 3.3
- apply the law of conservation of energy to energy transfers and transformations in electrical appliances 3.3
- **describe** the features of electrical circuits in the home, including safety features 3.3
- **outline** how electrical energy use is monitored and charged 3.3
- **investigate** the energy efficiency of domestic appliances 3.3
- **discuss** how the values and needs of contemporary society have led to a focus of scientific research on the efficient use of electricity 3.3

3.6.3 Meeting our future electricity needs

- **relate** developments in electronics to the growth in the use of electronic devices 3.4
- **describe** how generators create electricity and relate this to the commercial production of electricity in power stations 3.4
- **identify** examples of renewable and non-renewable energy sources 3.4
- **account for** the research and development of technologies using non-renewable energy sources 3.4
- **describe** scientific and technological developments in the generation of electricity using renewable energy 3.4

Individual pathways

ACTIVITY 3.1	ACTIVITY 3.2	ACTIVITY 3.3
Investigating electricity doc-10639	Analysing electricity doc-10640	Investigating electricity further doc-10641

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FOCUS ACTIVITY

Option 1

Conduct a survey of the electrical appliances on display in a department store. Focus on a range of models within a category of appliance such as refrigerators or washing machines. Collect data on each model including the capacity, e.g. fridge volume, as well as the energy rating, estimated annual energy use, cost and any special features. Construct a poster or multimedia presentation to critique the models surveyed. Include a calculation of the estimated running costs, appropriate graphs to display your data and photos of each of the models.

Option 2

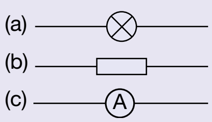
Join with other members of your class for an energy summit. As a contributor you will research a method for generating electricity using any renewable or non-renewable energy source and promote it as the best way of meeting Australia's future electricity needs. For the method of generation selected, examine how the technology works as well as the advantages and disadvantages of this technology. Present your information in the summit and be prepared to critique other methods of electricity generation and to defend your mode of generation. Be sure to have lots of facts and figures at your fingertips to present objective arguments and to counter the proposals of others.

Access more details about focus activities for this topic in the Resources tab (doc-10638).

3.6 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. **Define** each of the following terms:
   (a) electric current
   (b) load in a current
   (c) components in series
   (d) components parallel
   (e) conductor.
2. Draw a circuit diagram to show how a voltmeter and ammeter are used to measure the voltage drop and the current flowing through a single light globe connected to a 6-volt DC power supply. Label the positive and negative terminals of the power supply and each side of the meter with + and – symbols.
3. Complete the table at right by **identifying** the missing quantity, unit or abbreviation.
4. **Identify** each of the following circuit components:

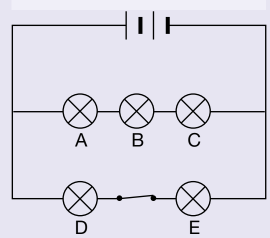


Electrical quantities and their units

Quantity	Unit name	Unit abbreviation
Voltage	volt	
Electric current		A
	ohm	
Electrical power		W
Electrical energy		J
		kWh

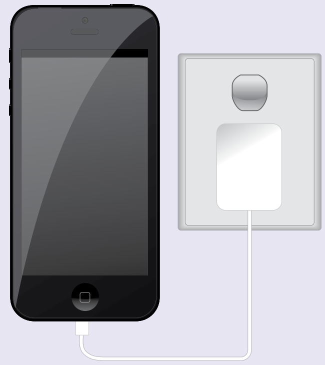
Questions 5–11 refer to the circuit diagram at right. The light globes, labelled A–E, are identical to each other.

Circuit diagram for questions 5–11



5. **Identify** the light globe(s) connected:
   (a) in series with globe A
   (b) parallel with globe A.
6. The electric current flowing through globe B is 200 mA and the electric current flowing through globe D is 300 mA. **Predict** the electric current flowing:
   (a) through globe A
   (b) from the power supply
   (c) through globe E.
7. If the voltage drop for globe C was measured to be 4 volts, **predict** the voltage across:
   (a) globe A
   (b) the terminals of the power supply
   (c) globe E.
8. If the filament in globe B was to break, **predict** which of the light globes would remain glowing.
9. If the switch in the circuit was opened, **predict** which light globe(s) would stop glowing.
10. **Outline** how you could make all of the light globes stop glowing without opening the switch or turning off the power supply.
11. The voltage across globe C is measured to be 4 volts and the current flowing through it is 200 mA.
    (a) **Identify** the electric current flowing through globe C in amps.
    (b) **Calculate** the resistance of globe C while this current is flowing.
12. Design and draw a circuit diagram for a studio apartment containing an AC power source, a fuse, three parallel lights with two master switches that can operate all three lights simultaneously from different locations in the apartment.
13. Power points in Australia provide 240 V AC electricity. **Explain** what this means.
14. One of the arguments against the use of coal-fired power stations for generating electricity is the air pollution they cause. However, hydro-electric power stations can also damage the environment. **Explain** how.
15. **Identify** the method(s) of generating electricity that:
    (a) could be described as renewable energy sources
    (b) involve the use of energy from the sun
    (c) create thermal pollution.

16. The mobile phone charger shown in the figure at right contains a transformer and a rectifier.
    Outline the purpose of the:
    (a) transformer
    (b) rectifier.



17. **Explain** how each of the following electrical safety devices protects us from injury:
    (a) earth wire
    (b) circuit breaker
    (c) safety switch.
18. **Calculate** how much electrical energy, in kilowatt hours, is transformed by a 70-watt electric blanket over a period of eight hours.
19. **Calculate** how much it would cost to heat a frozen pie in a 650-watt microwave oven if it takes two minutes to heat the pie and the cost of electrical energy is 14 cents per kilowatt-hour.
20. **Describe** the principle by which generators create an electric current.
21. **Explain** why the development of electronics with integrated circuit technology has revolutionised society.
22. **Describe** the process by which a nuclear reactor generates electricity.
23. Draw a table to **summarise** each type of renewable energy source for electricity generation in Australia. In the first column, **identify** each energy source and in the second outline what each involves.

Test yourself

1. A useful analogy for an electric circuit is a bakery supplying bread to a supermarket. What do each of the following in the analogy equate to in an electric circuit? **(1 mark)**

	The bakery	The delivery van	Speed of the delivery vans	The loaves of bread	Supermarkets requiring delivery
A	Electrical energy	Battery	Current	Resistance	Charges
B	Battery	Charges	Current	Electrical energy	Resistance
C	Electrical energy	Current	Charges	Resistance	Battery
D	Charges	Current	Resistance	Electrical energy	Resistance

2. The correct units of measurement for voltage, charge, current and resistance are
   (a) amperes, coulombs, volts and ohms.
   (b) volts, coulombs, amperes and ohms.
   (c) joules, coulombs, amperes and ohms.
   (d) joules, amperes, coulombs and degrees Celsius. **(1 mark)**
3. A 6.0 V DC power source supplies two light globes connected parallel. If the resistance of the circuit is 12 Ω, the voltage and current for each light globe is
   (a) 3.0 V and 0.5 A.
   (b) 6.0 V and 0.5 A.
   (c) 3.0 V and 0.25 A.
   (d) 6.0 V and 0.25 A. **(1 mark)**
4. A 1000 W toaster takes 2 minutes to toast a slice of bread. The energy used over that time is
   (a) 120 000 J.
   (b) 2000 J.
   (c) 1000 J.
   (d) 33 J. **(1 mark)**
5. A circuit is supplied with 12 V DC. Two identical globes are connected parallel. If the current through one of the globes is 0.3 A, **calculate**:
   (a) the total current **(1 mark)**
   (b) the total resistance in the circuit. **(1 mark)**

6. Create a flow chart that shows all of the energy transformations and transfers that take place in the generation and transmission of electricity from the time that brown coal begins to burn until the time that you use a hair dryer to dry your hair. Remember that during each energy transformation or transfer, some of the energy is 'lost' to the environment as heat. **(4 marks)**

learnon RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 3.5: Electricity at work puzzles (doc-12751)

Complete this digital doc: Worksheet 3.6: Electricity at work summary (doc-12752)

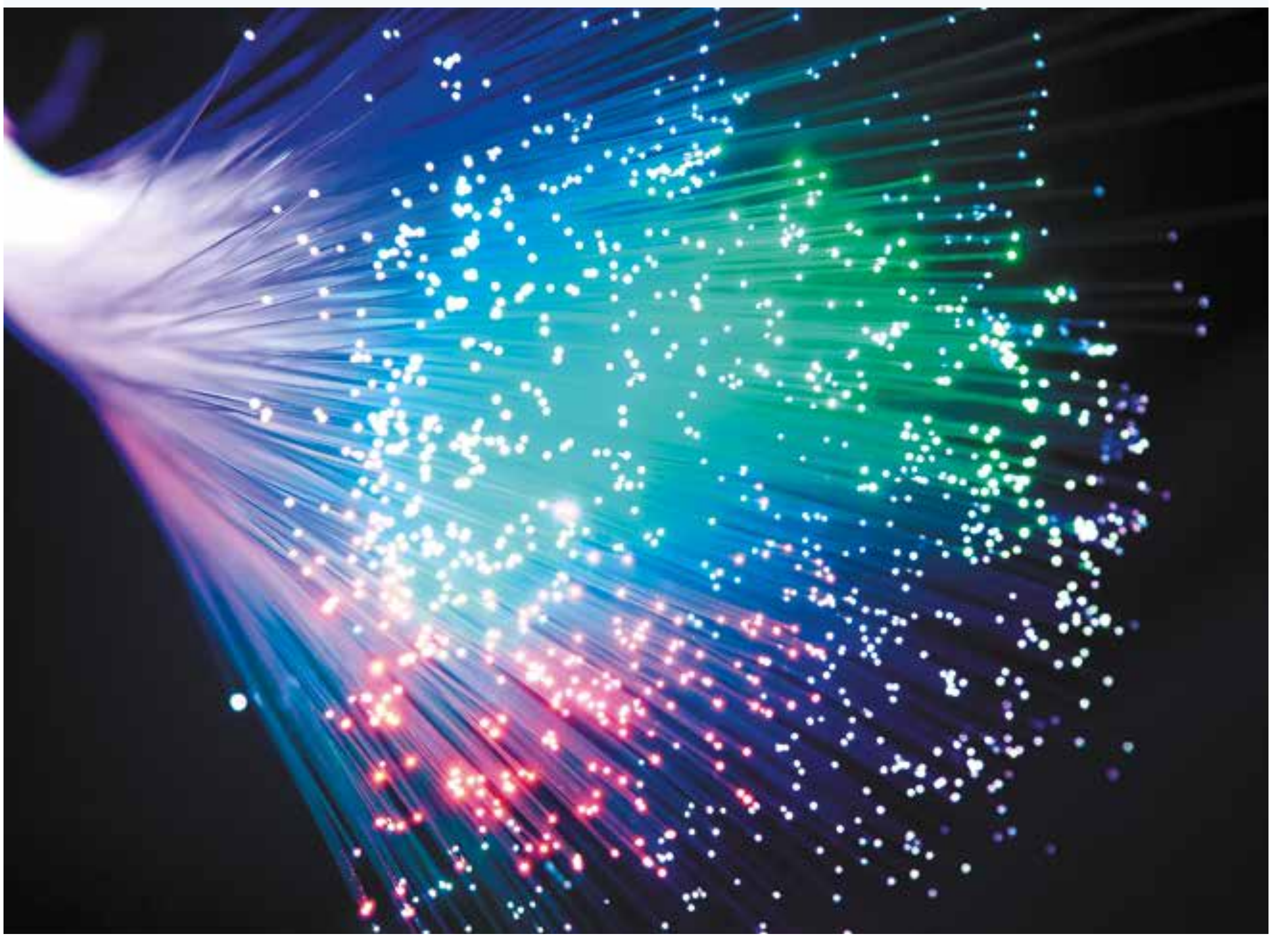
TOPIC 4
Invisible waves

4.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

LEARNING SEQUENCE

Optic fibre technology is set to revolutionise digital communication.



4.1.1 Why learn this?

Light and sound are forms of energy carried by invisible waves. Our senses are attuned to detecting them, and many household devices like musical instruments, mirrors and sunglasses utilise them.

Light is just one example of electromagnetic radiation which is becoming increasingly important in the development of technologies used for communication, such as mobile phones, and for entertainment like radios, televisions and A/V remote controls. In addition, electromagnetic waves in the form of X-rays and gamma rays assist in the diagnosis and treatment of injuries and diseases.

As optic fibre technology takes off in Australia, electromagnetic waves are set to revolutionise computer and phone use in the near future allowing even faster communication around the planet and almost unlimited possibilities in the use of digital media.

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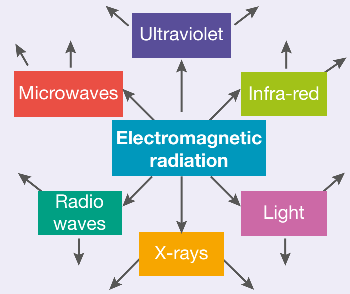
Thinking about communication

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Most of our communication today relies on electromagnetic radiation but this was not always the case. The table below contains some key steps in the history of communication. Draw a timeline to scale and label the key events from the table.

Time	Development
26 000 BC	Oldest known Indigenous Australian rock art in Northern Territory
c. 3000 BC	The Egyptians develop hieroglyphic writing.
776 BC	The first recorded use of homing pigeons, used to send messages to the Athenians, announcing the winner of the Olympic Games
c. 500 BC	Papyrus rolls made of dried reeds, the precursor to modern paper, are used.
37 BC	The first records indicating Roman Emperor, Tiberius used mirrors to send messages
105 BC	Paper as we know it is invented in China.
1041 AD	Movable type printing (made of clay) is invented in China.
1455 AD	Johannes Gutenberg invents a printing press with movable metal type.
1843	Samuel Morse invents the first long distance electric telegraph line utilising Morse code.
1876	Alexander Graham Bell patents the electric telephone.
1901	Guglielmo Marconi transmits radio signals from Cornwall to Newfoundland — the first radio signal across the Atlantic Ocean.
1916	The first radios with tuners become available allowing listeners to tune into different stations.
1927	Television broadcasting begins in England.
1951	Computers are first sold commercially.
1966	Xerox invents the Telecopier — the first successful fax machine.
1966	Launch of A Intelsat II, first satellite link between Australia and overseas
1979	The first mobile phone communication network starts in Japan.
1986	The first fibre-optic cable across the English Channel begins service.
1994	American government releases control of internet and WWW is born — making communication travel at light speed.
2009	Australia launches a program to install optic fibre nationwide.

2. In our homes and at work we use a range of technologies that utilise electromagnetic radiation. Use a mind map to brainstorm devices or applications that rely on the electromagnetic radiation identified at right.
3. Morse code is illustrated below.
   (a) Write a message to a student in your class using Morse code while they write one to you. Decipher each other's message.
   (b) Refer to the timeline in question 1 to identify the technology that replaced Morse code and explain the advantages that it has.



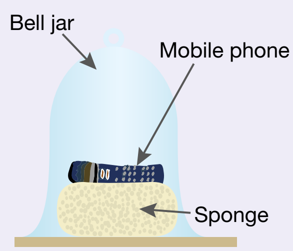
A • –	H • • • •	O – – –	V • • • –
B – • • •	I • •	P • – – •	W • – –
C – • – •	J • – – –	Q – – • –	X – • • –
D – • •	K • – •	R • – •	Y – • – –
E •	L • – • •	S • • •	Z – – • •
F • • – •	M – –	T –	
G – – •	N – •	U • • –	

1 • – – – –	7 – – • • •
2 • • – – –	8 – – – • •
3 • • • – –	9 – – – – •
4 • • • • –	0 – – – – –
5 • • • • •	. (Full stop) • • • • • •
6 – • • • •	, (Comma) • – • – • –

Rules

1. A dash lasts as long as three dots.
2. A space as long as one dot is left between each pulse.
3. A space as long as one dash is left between each letter of a word.
4. A space as long as five dots is left between each word of a sentence.

4. Compare the transmission of sound waves and radio waves to and from a mobile phone by conducting this simple experiment.
   - Place a mobile phone that has a loud ring tone in a bell jar supported by a sponge.
   - Try calling the mobile phone with the bell jar containing air and try again with the air removed by a vacuum pump.
     Does removing the air prevent the radio wave reaching the mobile phone in the bell jar or prevent the sound of the ring tone from reaching you outside the bell jar?



4.2 Waves — carriers of energy

4.2.1 The transformation and transfer of energy

Light and sound are forms of energy and, like other types of energy such as heat, electrical and chemical energy, they can be transformed or converted into other forms of energy. In photosynthesis for example, plants convert light into chemical energy in the form of sugar. Some homes have solar panels installed. The photovoltaic cells in these panels convert light to electrical energy. Even vision relies on special cells in the retina inside the eye, to transform light into small electrical impulses that are transmitted to the brain.

Sound energy is transformed into electrical energy by microphones. Amplifiers then channel this electrical signal to loudspeakers which convert the electrical energy back to sound again.

The transfer of energy does not involve conversion to another form; rather, energy remains in its original form but travels to a new medium or region. Light energy from the sun, for example, is transferred through space and the Earth's atmosphere and into the sea, allowing marine algae to photosynthesise in shallow water along the coastline.

Heat, or thermal energy is transferred spontaneously from a region of high temperature to a region of cold temperature through one or more of the following processes: conduction, convection and radiation. Heat transfer by conduction occurs mainly in solids, while convection occurs generally through liquids and gases. Radiation can occur through any space, even in a vacuum.

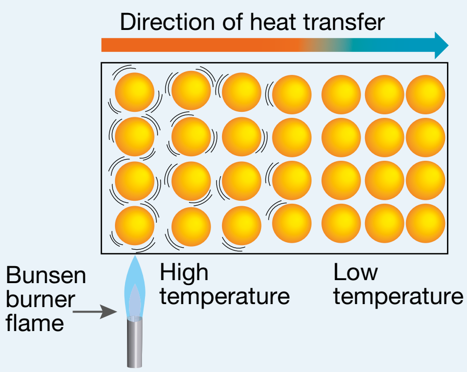
Heat transfer by conduction

Heat travels by conduction when fast-moving particles collide with other nearby particles, making them move faster. If you heat one end of a metal bar, the energy is transferred from the hot end to the cold end by atoms of that metal bumping into one another. Heat can travel by conduction through objects, or from one object to another, such as from a cooktop to a saucepan.

When particles are heated (for example, with a flame), they start to move more quickly.

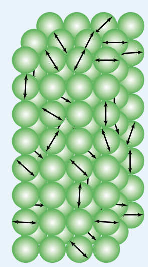
When the fast-moving particles collide with other particles, they cause nearby particles to start vibrating more quickly as well.

Eventually, as particles keep colliding with others, some of their energy is transferred along the object. This process is known as conduction.

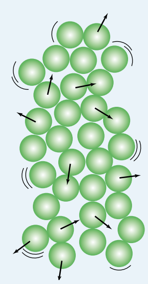


Conduction in solids, liquids and gases

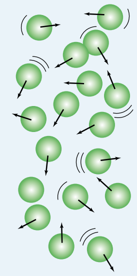
The particles in a solid are packed closely together. If some particles receive heat energy and begin to move faster, they collide easily with other particles nearby and pass the heat energy along.



The particles in liquids are further apart than the particles in solids. When some particles receive heat energy and start to move faster, they collide with other particles. But the distance between the particles means that there are fewer collisions. So, heat is transferred by conduction more slowly in a liquid than in a solid.



The particles in a gas are far apart. Heat does not travel easily by conduction through gases.



Heat travels by conduction at different speeds, depending on the type of material and its state of matter. Heat travels more quickly in solids than in liquids or gases because conduction occurs more quickly when the particles in an object are closer together. Gases are the poorest conductors because the particles in them are far apart. While solids are usually very good conductors of heat because the particles in them are packed closely together, not all solids conduct heat well. Metals are generally good conductors of heat and electricity, while non-metals like glass, plastic and wood do not conduct as well. The free, mobile electrons in metals that allow them to conduct electricity also assist in the transfer of heat energy through the metal. Materials that conduct heat and electricity poorly are called **insulators**.

INVESTIGATION 4.1

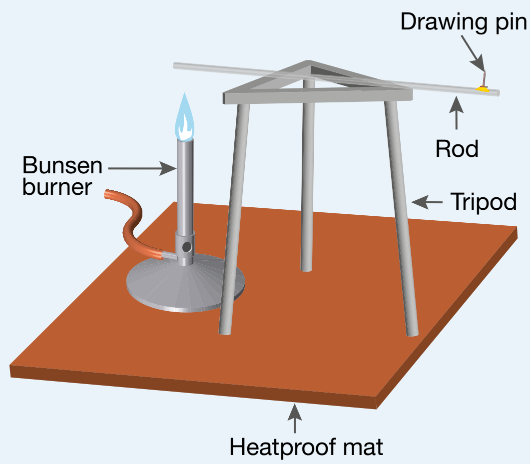
Investigating heat transfer by conduction

AIM: To investigate the rates of conduction in metals and non-metals

You will need:

heatproof mat, Bunsen burner and matches
glass rod
aluminium rod
Vaseline
drawing pin
stopwatch

- Place a rod of aluminium on top of a tripod so that it is stable.
- Place a lump of Vaseline 15 cm from one end of the rod and position a drawing pin on the Vaseline so that it is upright.
- Light the Bunsen burner.
- Heat the near end of the rod (away from Vaseline and drawing pin) with the blue flame of the Bunsen burner.
- Time how long it takes for the drawing pin to fall.
- Repeat the experiment with a glass rod and record your data in a table.



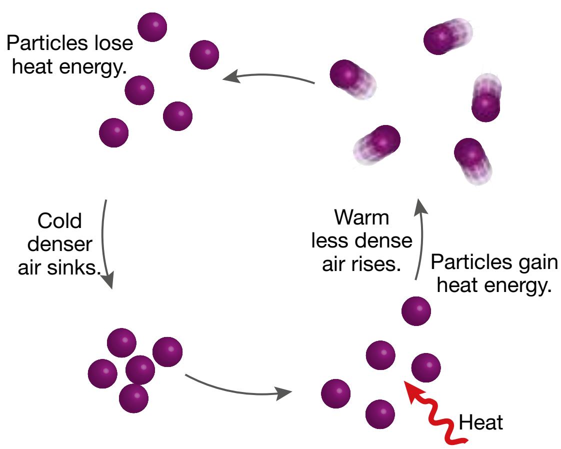
Discussion

1. Through which rod was heat conducted the fastest? Explain why in terms of the particles making up that material.
2. For this investigation identify the:
   (a) independent variable
   (b) dependent variable
   (c) variables that you managed to control.
3. Describe improvements that you would make to the design of the experiment, given a wider choice of equipment and why you would make those changes.

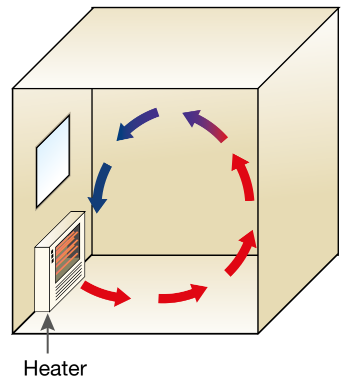
Heat transfer by convection

The transfer of heat by conduction in liquids and gases is not very efficient; instead, heat travels through these substances by **convection**. Convection can be best explained by examining how convection heaters work. These heaters blow out warm air which then rises. This is because the particles of warm air have greater kinetic energy and so the moving particles take up more space, making the warm air less dense than the cooler surrounding air. As the warm air rises, it transfers some of its energy to the surroundings causing the air to cool. As it cools the air loses kinetic energy, bringing the particles closer, resulting in the density of the air increasing and so it begins to fall. This flow of warm air up and cool air down creates a circular current called a convection current. The same pattern can be seen in liquids.

Modelling a convection current



Convection currents consist of warm air rising and cool air falling.



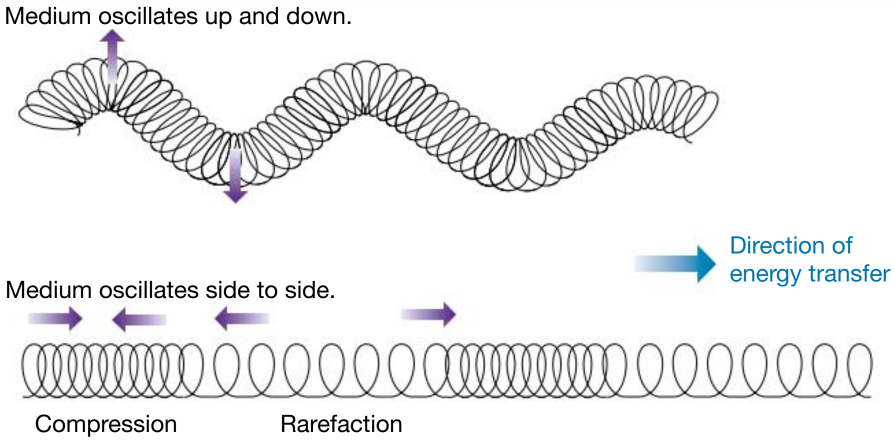
4.2.2 Waves — carriers of energy

Like heat, sound and light energy can be transferred from one place to another. However, sound and light travel as waves and it is these waves which transfer or propagate that energy. The circular ripples created when a stone is dropped in a still pool of water are an example of waves propagating energy. The stone falling through the water causes the water to bob up and down, creating waves. The energy of the oscillating water moves outwards from the centre of the disturbance, creating a circular pattern of waves.

Types of waves

Water waves created on the surface of a lake are examples of **transverse waves**. Transverse waves can be demonstrated in a slinky too. The medium or material carrying the transverse wave oscillates up and down, at right angles to the direction of energy transfer. In fact, the word ‘transverse’ means ‘across’. Transverse waves consist of a series of crests and troughs. In transverse waves, the wavelength is the distance between two adjacent crests, or two troughs, or the distance between any two corresponding points on neighbouring waves. The amplitude of a wave is the maximum distance that each particle moves away from its usual resting, or equilibrium, position.

Two types of energy transfer in a slinky: a transverse wave (top) and a compression wave (bottom)



INVESTIGATION 4.2

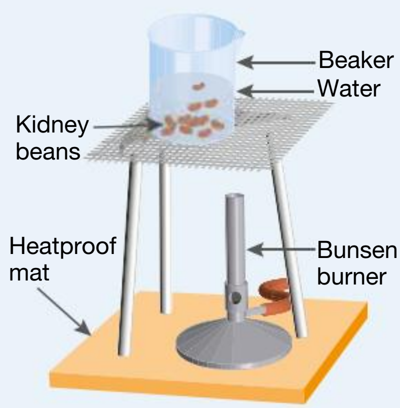
Investigating heat transfer by convection

AIM: To investigate convection currents

You will need:

600-mL beaker
6 red kidney beans
tripod
heatproof mat
gauze mat
Bunsen burner and matches

- Fill a 600-mL beaker with approximately 400 mL of water.
- Add approximately 6 red kidney beans to the water.
- Set up the equipment as illustrated at right.
- Light the Bunsen burner and position it to heat the edge of the beaker with a blue flame.
- Observe the motion of the kidney beans as the water heats and allow it to boil for a minute or two.
- Draw a diagram to illustrate the motion of the kidney beans.



Discussion

1. Describe the pattern in the motion of the kidney beans.
2. Assuming that the kidney beans are carried by the currents of water moving in the beaker, explain why the currents travel in the pattern you observed by referring to the particles (molecules) of water.

4.2.3 Sound

Sound energy is not carried as transverse waves but rather in the form of compression waves. Sound is created by fast back and forth movements called vibrations. When you create sound by striking a drum, the drum skin causes air particles around the drum to be pushed together, then a moment later spread apart. The energy of the vibrating drum skin is transferred to the nearby air particles, making them vibrate as quickly as the drum skin. The vibrating air particles bump into nearby air particles, making them vibrate as well. This creates a series of **compressions** (a region of air particles that are close together) and **rarefactions** (a region of air particles that are spread apart) that we call **sound waves**.

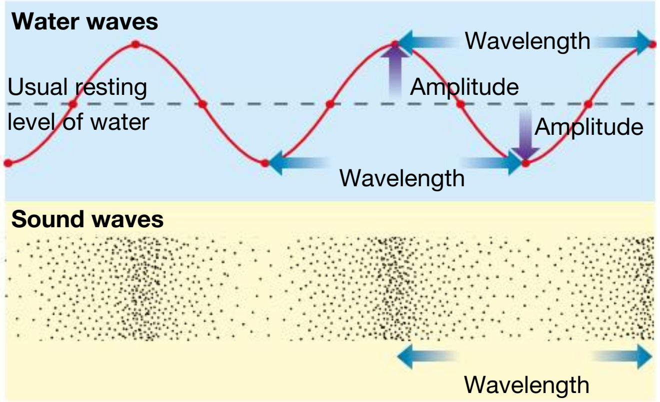
In compression waves, the medium oscillates backwards and forwards parallel to the direction in which the energy is transferred. Compression waves are also known as **longitudinal waves**. The wavelength of a compression wave is the distance between the centre of two adjacent compressions or two adjacent rarefactions.

When a mobile phone rings in a bell jar, the sound can be heard clearly. When the air in the bell jar is sucked out by a vacuum pump, the sound fades. If all of the air is removed, no sound can be heard at all. This is because sound cannot travel through empty space. Sound energy can only be transferred through a medium in which vibrating particles carry that energy. In empty space, there are no particles to vibrate. Light on the other hand does not require a medium to travel through. It can travel through a vacuum. So you can still see the mobile phone, even if you can't hear it.

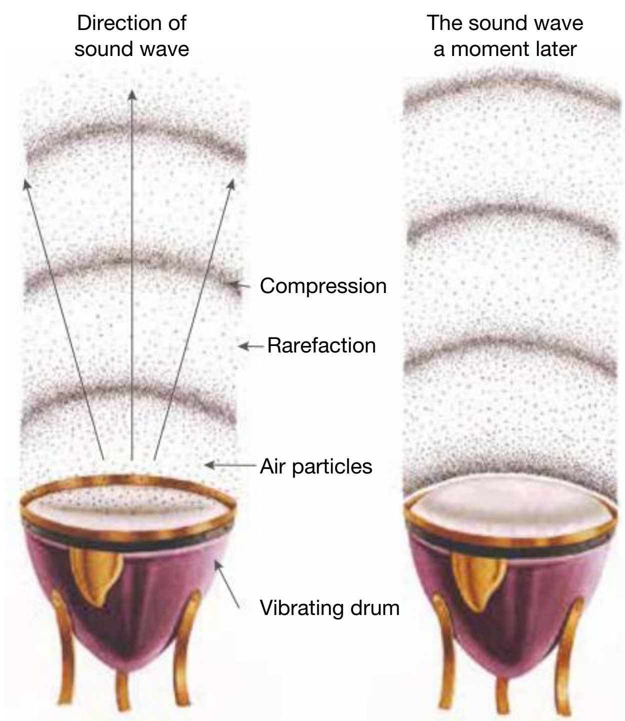
The frequency of a vibration or wave is the number of complete waves generated per second. Frequency is measured in hertz (Hz), a unit named after Heinrich Hertz, the German physicist who, in 1887, was the first to detect radio waves. One hertz is equal to one oscillation or wave per second, so a middle C note produced by a musical instrument creates sound waves corresponding to 256 vibrations per second or a frequency of 256 hertz. The frequency of a sound determines its pitch. High-frequency vibrations produce high pitch, and low-frequency vibrations produce low pitch.

As the frequency of a sound gets higher, that is, as more compressions are produced per second, the compressions become closer

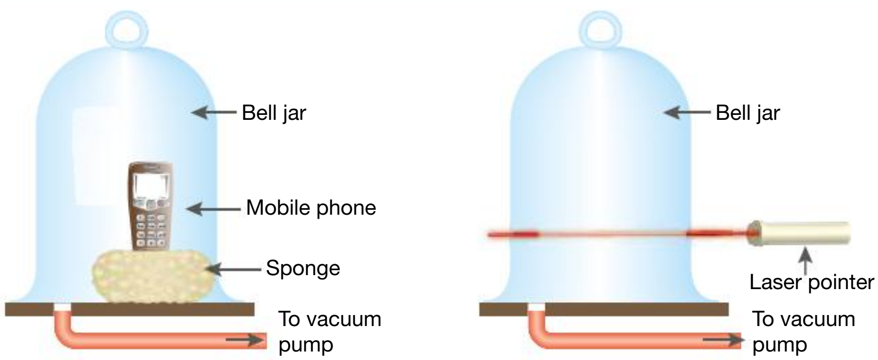
Wavelength and amplitude are useful in describing waves.



Sound waves consist of a series of compressions and rarefactions.



Sound waves require a medium to travel through; light does not.



together. Thus, low-frequency sounds have long wavelengths and high-frequency sounds have short wavelengths.

While the frequency of a sound wave determines its pitch, the amplitude determines its loudness; higher amplitudes correspond with louder sounds.

INVESTIGATION 4.3

Frequency and wavelength

AIM: To investigate how frequency relates to wavelength

You will need:

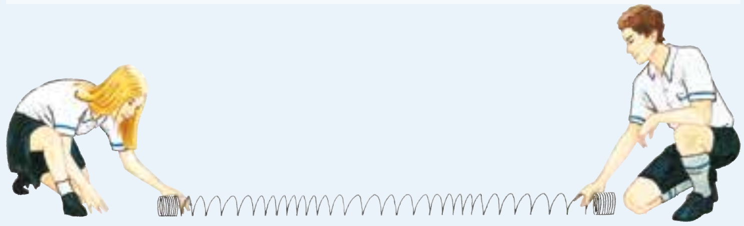
slinky
water soluble marker
stopwatch

- Work in groups of four and allocate roles based on the skills and interest of each student.
- Two members of the group hold the ends of a stretched slinky.

Part A: Compression waves

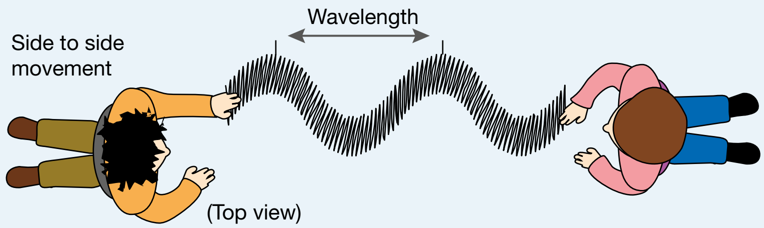
- Create pulses of compression waves by flicking an end of the slinky in and out.
- Observe the compressions and rarefactions as they move through the stretched slinky.

Modelling compression waves using a slinky spring



Part B: Transverse waves

- Create a transverse wave pulse by flicking an end of the slinky side to side once or twice along the ground.
- Observe the transverse pulse as it moves through the stretched slinky.
- Now create continuous transverse waves by flicking the slinky side to side along the ground at a constant rate.
- While the transverse waves are in motion:
  – another student records the time taken for five to-and-fro movements by the group member creating the waves
  – a fourth group member marks the position on the floor of two adjacent crests of the transverse wave.
- Repeat this experiment, but this time create transverse waves with a smaller wavelength by flicking the slinky side to side at a faster rate.



- Copy and complete the table below. The frequency for each experiment is calculated as follows:

$$\text{Frequancy (Hz)} = \frac{\text{5 waves}}{\text{time taken for 5 waves}}$$

Transverse wave motion	Wavelength(m)	Time taken for 5 waves (s)	Frequency (Hz)
Slow rate			
Fast rate			

Discussion

1. Copy and complete the table below to compare the compression and transverse waves in terms of the direction in which the medium (slinky coils) moves and the direction of the wave as pulses are created.

Type of wave	Direction of movement of medium	Direction of wave movement
Compression		
Transverse		

2. Identify which of the two transverse waves had the greatest frequency and outline how an increased frequency can be created.
3. The velocity of a wave can be calculated using the wave equation that follows:

$$\text{Velocity (m/s)} = \text{frequency (Hz)} \times \text{wavelength (m)}$$

   (a) Calculate the velocity of the two transverse waves.
   (b) Analyse whether there was a significant change to the velocity of the transverse waves in the slinky in each experiment. Suggest a reason for this.

INVESTIGATION 4.4

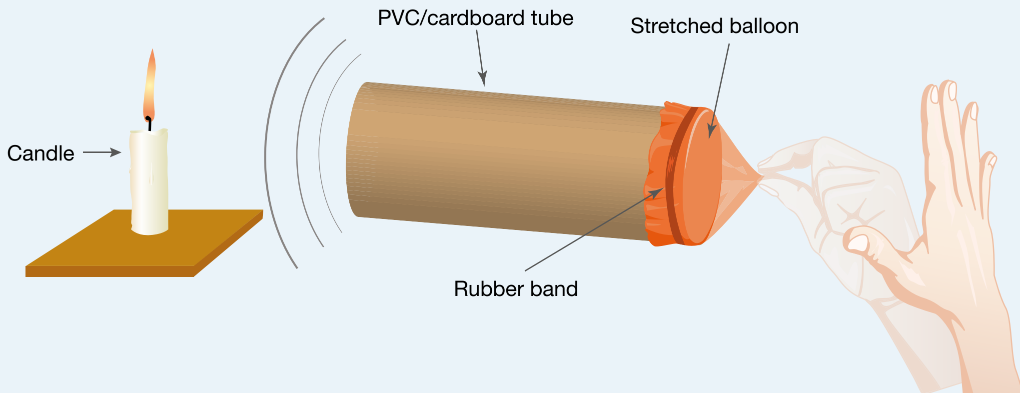
Target practice

AIM: To investigate the most effective design for an air cannon

You will need:

PVC or cardboard tubes of various lengths and diameters
balloon
scissors
rubber band
ruler
candle and holder
matches
metre ruler

- Select a tube. Measure and record its length and diameter.
- Build an air cannon by cutting the neck from the balloon. Open the balloon and stretch it over the end of the tube and secure it firmly to the tube using the rubber band.
- Light the candle and place it on a bench.
- Starting just in front of the candle, try to blow out the candle by pinching and then pulling and releasing the stretched rubber sheet at the end of the balloon. If you were successful move back away from the candle and try again. Record the maximum distance from which you can blow out the candle.
- Collate the class's results, including the lengths and diameters of the tubes.
- You could design a separate experiment to determine the tube diameter and length that are most effective at blowing out the candle.



Discussion

1. Explain why you were able to blow out the candle.
2. Identify an independent variable in this experiment.
3. Identify the dependent variable in this experiment.
4. Analyse the class's results to determine the most effective dimensions for your air cannon.

The speed of sound

Sound energy is carried by compression waves and so relies on the collision of neighbouring particles in a medium. In a medium in which the particles are more tightly packed and have less distance to travel to collide, such as in a liquid or a solid, sound waves travel faster. In air, sound travels at a speed of approximately 340 m/s, while in sea water sound waves travel at 1533 m/s — well over 4 times faster than in air. Several ocean-dwelling animals rely upon sound waves to communicate with other animals and to locate food. These animals make use of this method of communication effectively over long distances because sound travels so much faster in water. Dolphins for example use **echolocation** (reflected sound) to locate food and to communicate with each other while travelling in groups. They send out high frequency sound pulses, or ultrasound, that are reflected back when they strike a target. This echo helps the dolphin to identify the size, shape and direction that an object is moving.

The speed of sound in gases depends on temperature. Sound travels faster in warm air as the particles of mainly nitrogen and oxygen have more kinetic energy and so move more quickly.

The speed of sound through various materials is shown in the table at right.

A jet plane travelling faster than the speed of sound in air is said to be travelling at supersonic speeds. The speeds of supersonic objects are often expressed in terms of a Mach number — the ratio of the object's speed to the speed of sound in the surrounding air. Thus an object travelling at Mach 2 is travelling at twice the speed of sound. Supersonic aircraft produce a sonic boom as pressure waves produced at the nose and tail of the plane are forced together at these high speeds.

Dolphins travel in large groups, therefore sound is important for communication to maintain group structure.

	Material	Speed of sound (m/s)
Gases	Carbon dioxide (0 °C)	259
	Air (0 °C)	331
	Air (20 °C)	343
	Hydrogen (0 °C)	1 286
Liquids	Mercury	1 450
	Water	1 493
	Sea water	1 533
Solids	Rubber	1 600
	Copper	3 560
	Iron	5 130
	Pyrex glass	5 640
	Diamond	12 000

A Super Hornet jet travelling beyond the speed of sound generates a sonic boom. The pressure waves over the plane are visible as a cone-shaped cloud behind the plane. The origin of this cloud is still debated. It may be that a drop in air pressure around the plane occurs so moist air condenses there to form water droplets.

4.2.4 Ultrasound

While the human ear can detect sound frequencies between 20 and 20 000 Hz, frequencies well beyond the range of human hearing are used in a variety of useful technologies.

Sound with frequencies higher than those that humans can hear is called ultrasound. This image of an unborn baby is produced with ultrasound. To produce images like the one at right, ultrasound is sent through the mother's body.

Some of it is reflected from the surface of the baby. A computer is used to change the reflected ultrasound into an image. The images are used to check for problems during pregnancy.

Ultrasound is also used in industry to check for cracks in metal, drill holes in glass and steel.

Sonar

Ultrasound is used in *sonar* to produce images of underwater objects or the ocean floor.

1. Ultrasound is sent down into the water.
2. Objects under the water (and the ocean floor) reflect some of the ultrasound.
3. A receiver detects the reflected ultrasound.

Measuring sound

While we can hear sound waves, they are invisible. However, they can be studied by converting the sound energy into electrical energy using a device called a **cathode ray oscilloscope** (CRO). A microphone connected to the CRO measures the **air pressure** changes associated with the compressions and rarefactions of a sound wave and produces a graph on the CRO screen called a **waveform**. This allows us to record how quickly the sound wave makes the air vibrate and compare the energy levels of sound waves.

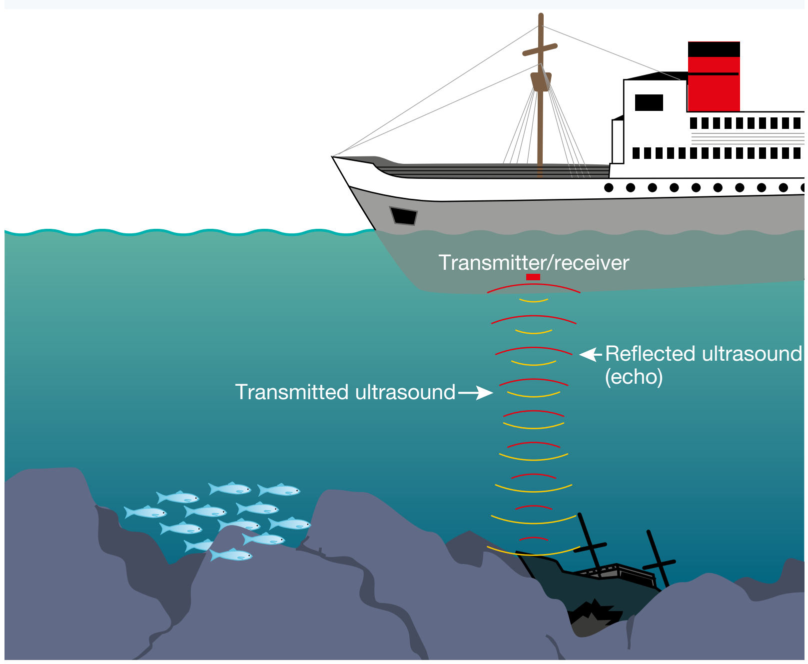
The **pitch** of a sound depends on how quickly it makes the air vibrate. High-pitched sounds have a high frequency and make the air vibrate quickly. As a result, they produce 'bunched-up' waveforms. Low-pitched sounds have a low frequency and make the air vibrate less quickly, so the waveforms are more spread out.

As in all waves, frequency is measured in Hz. High-frequency sounds are more high pitched than low-frequency sounds.

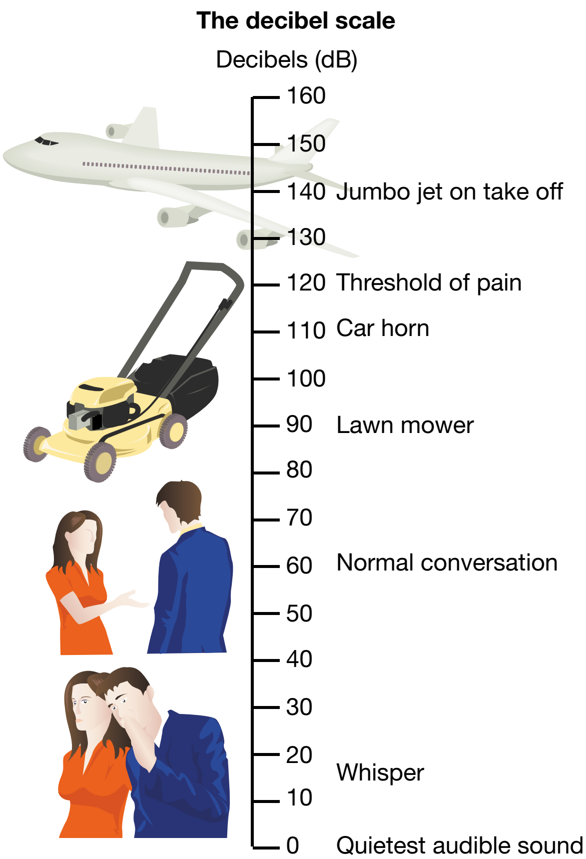
Loud sounds produce a tall waveform on a CRO display. This is because more sound energy produces a larger electrical signal. Soft sounds, on the other hand, produce a shorter waveform.

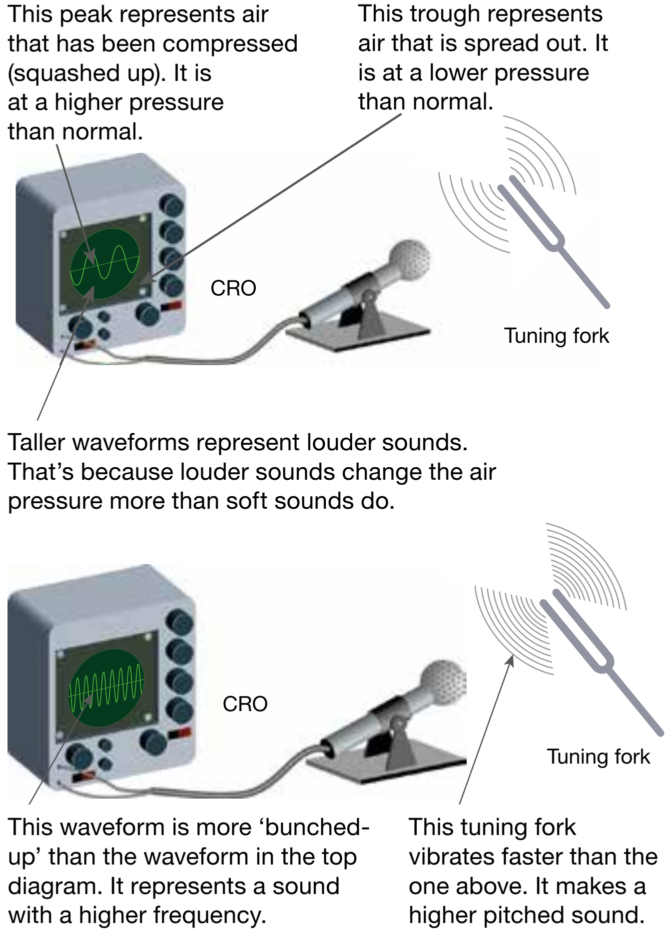
The decibel (dB) scale is commonly used to measure the sound level or loudness of sound. On the **decibel scale**, the quietest audible sound is 0 dB. Each tenfold increase in sound level is an extra 10 dB higher. So a sound 1000 times more powerful than the quietest audible sound is 30 dB. Some common sounds and their decibel ratings are shown on the following page.

A computer uses the time taken for the reflected ultrasound to return to the ship to calculate the depth of objects in the water. It can also map the ocean floor.



Any sound above 85 dB can cause **hearing loss**, and the loss is related both to the loudness of the sound as well as to the length of exposure. You know that a sound exceeds 85 dB if you have to raise your voice to be heard by somebody else.





HOW ABOUT THAT!

The calls of the blue whale, with sound levels of more than 180 dB, can be even louder than the launch of a rocket. Scientists working in the Southern Ocean recorded blue whale calls at this sound level and could, therefore, locate blue whales up to 200 km away.

INVESTIGATION 4.5

Sound proofing

AIM: To investigate the most effective material to insulate against noise

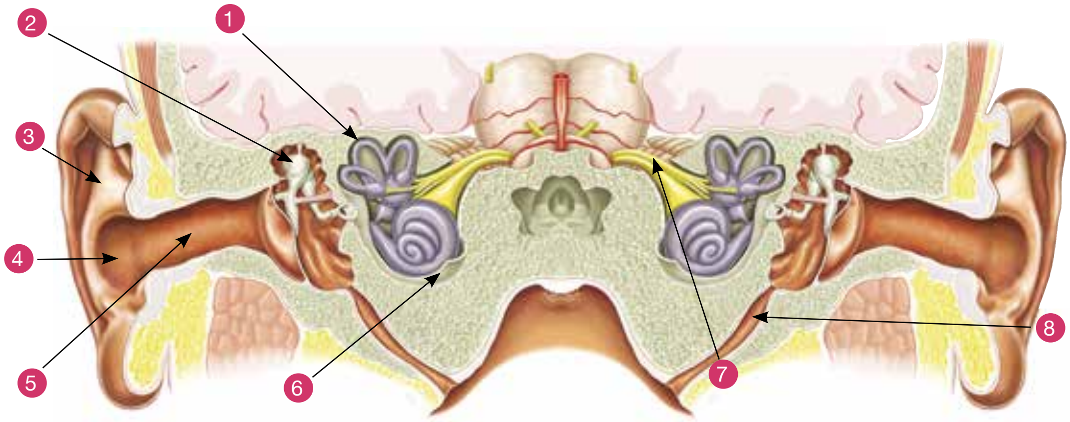
You will need:

variety of materials to test (such as wood, fabric, glass and cardboard)
source of sound (such as an MP3 player)
sound level meter or data logger and sound probe

- Design an experiment to investigate the most effective material to insulate against noise.
- Record your results in a suitable table and graph.
- Analyse your results to draw an appropriate conclusion.

4.2.5 The ear and hearing

The main function of the ear is to detect sound. It collects the energy of vibrating air and changes it into electrical signals, which are sent to the brain. Each ear has three main parts — the outer ear, the middle ear and the inner ear.



1. **Semicircular canals**
These three tubes have nothing to do with hearing. They control your sense of balance. When you move, fluid in the tubes flows past cells that sense the movement. These cells send signals to the brain. The signals tell you when you are moving and whether you are up, down or on your side. When you move around in circles quickly, the fluid moves quickly — even for a while after you stop. The messages from the cells in the **semicircular canals** tell your brain that you are still moving. However, the messages from your eyes tell the brain that you are not moving. These mixed messages to the brain make you feel dizzy.

2. **Middle ear**
The middle ear contains the three smallest bones in the body. Together, they are known as the ossicles. These tiny bones send vibrations from the **eardrum** to the inner ear. They also make the vibrations larger. One of the ossicles (the stirrup) presses against a thin layer of skin called the oval window at the entrance to the inner ear.

3. **Auricle**
The outside part of the ear contains a spongy type of tissue called cartilage.

4. **Outer ear**
The outer ear collects the energy of the vibrating air and funnels it along the **ear canal**. The air along the ear canal vibrates. That makes the eardrum vibrate. High-pitched sounds make the eardrum vibrate quickly. Low-pitched sounds make the eardrum vibrate slowly.

5. **Ear canal**
The ear canal contains wax and tiny hairs to trap dust so that it doesn't get to the eardrum. If the wax builds up enough to block your ear canal, a doctor can remove it.

6. **Inner ear**
The inner ear is filled with fluid. The vibrations are passed along the fluid into a snail-shaped tube called the cochlea. The inside of the cochlea is lined with millions of tiny hairs. Each hair is attached to a nerve receptor. When the fluid vibrates, the hairs move. The receptors change the energy of the moving hairs into electrical energy and send signals through the **auditory nerve** to the brain. You interpret those signals as sound.

7. **Auditory nerve**
Nerves from the receptors in the **cochlea** merge to form this large nerve that sends signals to the brain.

8. **Eustachian tube**
This tube joins the middle ear to the nose and throat. It is usually closed. When the air pressure on the eardrum is not the same on both sides, the tube opens. Air then moves either into or out of the middle ear until the pressure is balanced again.
When the air pressure on one side of the eardrum changes quickly, you can feel a 'pop' as the **Eustachian tube** opens and air rushes through it. This happens when you are in a plane that is climbing steeply. The air pressure in the plane becomes less than the air pressure in your middle ear. The Eustachian tube then opens and some air moves from the middle ear to the nose and throat so that the air pressure on your eardrum is balanced.

HOW ABOUT THAT!

The aye-aye is a rare animal that lives on the island of Madagascar. It feeds at night and has goggle eyes and huge ears. The aye-aye searches for food by tapping one of its stick-like fingers on tree trunks. It listens to the sound as vibrations go through the wood. The sound tells it where gaps, cracks and hollows are under the bark and where tasty grubs are hiding. Then it chews through the wood and hooks out the grub with its long middle finger.

4.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note*: Question numbers may vary slightly.

Remember

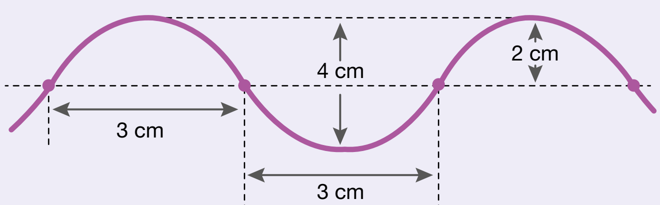
1. **Outline** how sound waves are created.
2. Draw and label a sound wave to demonstrate rarefactions and compressions.
3. Explain the difference between a compression and a rarefaction.
4. **Explain** why sound cannot travel through empty space.
5. **Describe** how the ear enables us to hear sounds.
6. **Define** the term ‘frequency’ and identify its unit of measurement.
7. **Identify** the feature of sound that frequency determines.

Think

8. **Explain** whether a Mexican wave, as seen among the crowds at some sporting events, is a transverse wave or a compression wave.
9. **Explain** why there are three semicircular canals in the ear rather than just one.
10. The speed of sound through various materials is listed at right.
    (a) **Identify** the trend in the data.
    (b) **Explain** why there is such a trend.

Material	Speed of sound (m/s)
Brick	3650
Sea water	1531
Iron	5950
Air (at room temperature)	343
Glass	5100
Distilled water	1497

11. **Identify** the wavelength and amplitude of the transverse wave shown in the diagram at right.



Investigate

12. You can feel your vocal cords vibrate if you place your hand gently over your throat while you talk. Say a long ‘hummmm’ in a deep voice and feel the vibrations. **Describe** how the vibrations change when you say ‘hummmm’ in:
    (a) a louder voice
    (b) a higher voice.
13. Is it true that older people find it more difficult to hear high-pitched sounds? Using secondary sources, **investigate** the normal frequency range of human hearing and whether that range depends on age.
14. The speed of sound through hydrogen gas is almost 1300 m/s, much greater than the speed through air and similar to the speed of sound through liquids. Use appropriate secondary sources to **explain** why.
15. Use the **Virtual oscilloscope** weblink in the Resources tab to simulate measuring sound energy.
16. Use the **My ear** weblink in the Resources tab to watch an animation of the effect of sound waves on cochlear structures.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Virtual oscilloscope

Explore more with this weblink: My ear

4.3 Light

4.3.1 Light

The transverse waves created in a slinky or in water are easily seen because the medium through which the wave travels is visible. Light is an example of an **electromagnetic wave**. Like water waves, electromagnetic waves are also transverse but they are not quite so easily seen.

Like all waves, electromagnetic waves transfer energy from one place to another. All electromagnetic waves travel through air at 300 000 kilometres per second. Unlike sound waves and water waves, electromagnetic waves can travel through a vacuum.

What's the difference?

Some of the differences between sound waves and electromagnetic waves are summarised in the following table.

Sound and electromagnetic waves: some differences

Sound waves	Electromagnetic waves
Compression (longitudinal) waves	Transverse waves
Travel through all solids, liquids and gases, but are unable to travel through a vacuum	Able to travel through most substances including through a vacuum
Speed in air between about 330 m/s and 350 m/s, depending on temperature	Speed in air about 300 000 km/s

The reflection of light

Light travels in straight lines. In diagrams, the lines used to show the path that light takes are called **rays**. Our eyes receive countless light rays reflected from objects that we view and the brain constructs an image of these objects using impulses from the eyes.

Individual rays of light are not visible but streams of light rays or beams of light may be seen when the light is **scattered**, or reflected from particles through which it travels and then redirected to the eye. For instance, beams of light can often be seen from car headlights on a foggy night as light is scattered from water vapour in the air.

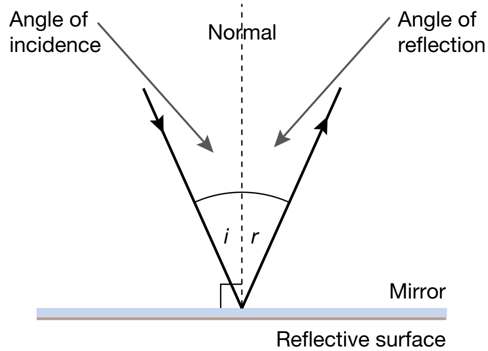
When light strikes a shiny surface like a mirror, light is reflected from that surface. Light reflected from a mirror follows the **law of reflection** which states:

The angle of incidence (i) = the angle of reflection (r)

These angles are measured from the **normal** (perpendicular) to the mirror surface.

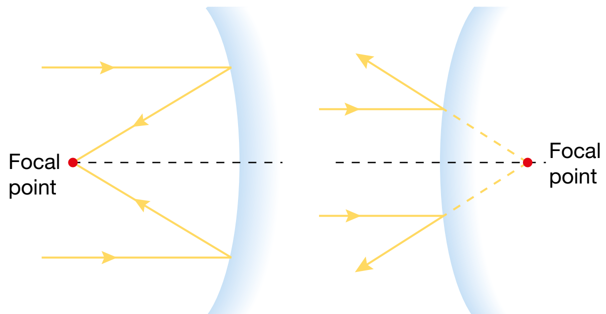
A beam of light may be visible if light is scattered by particles in the air, such as on a foggy night.

The reflective coating is commonly placed on the back surface of a flat or plane glass mirror to protect the coating from damage.



Reflection from curved mirrors

Flat mirrors, also called plane mirrors, are commonly found in the home. Curved mirrors have many applications too, including make-up mirrors, security mirrors in shops and safety mirrors at dangerous street intersections. Curved mirrors may be **concave** (curved inwards) or **convex** (curved outwards). Light reflecting from concave and convex mirrors also follows the law of reflection, such that the parallel rays of light are reflected to a **focal point** as shown at right.



Reflected light rays converge from a concave mirror.

Reflected light rays diverge from a convex mirror.

The reflected image of an object close to a concave mirror is enlarged, making concave mirrors useful for make-up mirrors.

Convex mirrors reflect light from a wide angle, creating an image reduced in size that captures much of the surrounds. These mirrors may serve as security mirrors in shops or to improve visibility at dangerous intersections.

INVESTIGATION 4.6

Reflection from plane and curved mirrors

AIM: To compare the light rays reflected from plane and curved mirrors

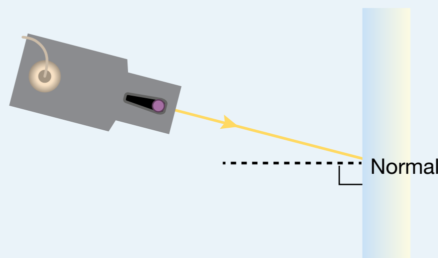
You will need:

ray box kit
DC power supply
protractor
ruler

The 'ray' box. It provides a way of tracing the path of light.

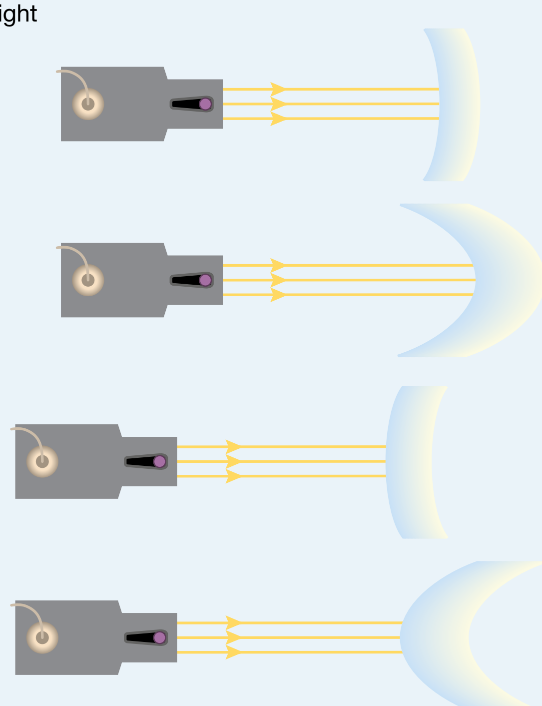
- A ray box contains a light source and a lens that can be moved to create rays of light that converge, travel straight or diverge. The light box can be placed on a sheet of paper making light rays reflected from the paper visible to the eye. Black plastic sliders can be placed in front of the light source to create a single ray of light or multiple parallel rays. The path of the rays can be traced on the paper by marking several small crosses along the path then drawing a line to represent the rays using a ruler.

Part A: The plane mirror



- Create a single narrow ray of light from the ray box by selecting the appropriate black plastic slide.
- Shine the ray onto a plane mirror tilted at an angle as shown at right.
- Draw a line along the plane mirror to mark its position then draw a series of small crosses to mark the position of the incident and reflected rays.
- Remove the mirror and draw lines to represent the incident and reflected rays. Use arrows to illustrate the direction of the light rays before and after striking the mirror.
- Using a protractor draw a dotted line 90° to the mirror to represent the normal as shown above right.
- Measure the incident angle and the reflected angle.

Part B: Curved mirrors



- Create multiple parallel rays of light from the ray box by selecting the appropriate black plastic slide.
- Shine the light rays onto spherical concave and parabolic concave mirrors as shown at right.
- Draw a line along the inner surface of each of the curved mirrors to mark their position then draw a series of small crosses to mark the position of the incident and reflected rays.
- Remove the mirror and draw lines to represent the incident and reflected rays. Use arrows to illustrate the direction of the light rays.
- Repeat this process for spherical and parabolic convex mirrors as shown at right.
- Create parallel rays of light from the ray box by selecting the appropriate black plastic slide.

Discussion

1. Compare the incident and reflected angles. Discuss whether your data follows the law of reflection.
2. Describe what happens to parallel rays of light striking concave mirrors.
3. Compare the reflected rays of light from the two concave mirrors.
4. Explain why parabolic reflectors serve as more efficient receivers for communication dishes.
5. Describe what happens to light striking convex mirrors.

Just passing through

Shiny surfaces reflect light but if a surface absorbs light it is said to be **opaque**. If most of the light travels through a material, the surface is called **transparent** because enough light passes through to enable objects on the other side to be clearly seen.

Some surfaces allow just enough light to travel through to allow objects to be detected on the other side, but they scatter so much light that the objects are not clearly visible. Frosted glass used in bathroom windows is an example of this. Such materials are said to be **translucent**.

Transparent

Translucent

Opaque materials

4.3.2 Refraction — bending light

Although it doesn't look like it, the stem of the flower at right is close to straight. Light from the part of the stem above the water travels in a straight line through the air to your eyes. Light reflected from the lower part of the stem travels firstly through water and then through the air. It bends when it emerges into the air.

Light normally travels in straight lines. However, under certain conditions, it is possible to change the direction of light. In the example on the next page, the light has been bent. Light can be made to bend by passing it through different transparent media. This bending of light through different media is called **refraction**.

As light travels from water to air, it changes direction.

Changing the speed of light

When light travels from one transparent medium to another, it speeds up or slows down. For example, when light travels from air to water it slows down. When it travels from water to air, it speeds up.

The bending of a light ray as it passes from one medium to another is caused by the light's change in speed. The speed of light through different media is given in the table below.

Medium	Speed of light (10^8 m/s)
Vacuum	3.00
Air	2.997
Water	2.25
Crown glass (used in lenses)	1.97
Perspex	2.05
Diamond	1.24

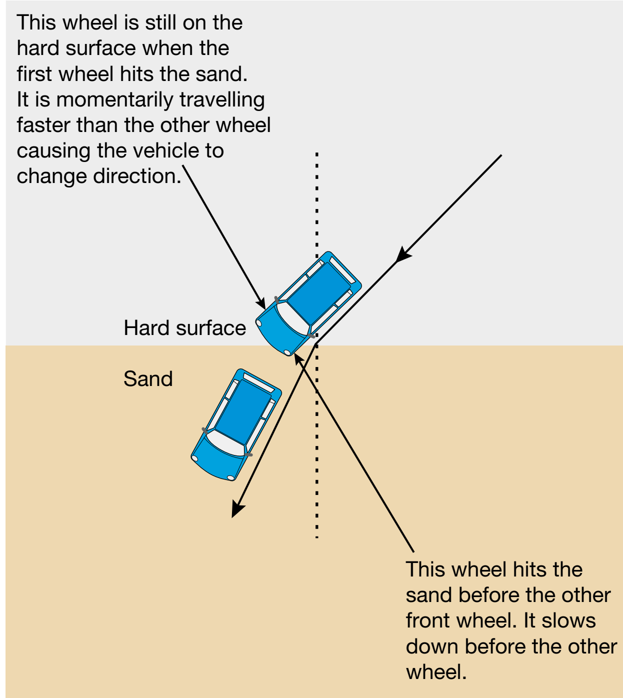
Imagine driving a vehicle from a hard surface onto soft sand. If both wheels strike the sand at the same time, they will slow down at the same time and the vehicle will remain straight. However, if one wheel hits the sand before the other, the wheels will momentarily be travelling at different speeds. The vehicle will change direction.

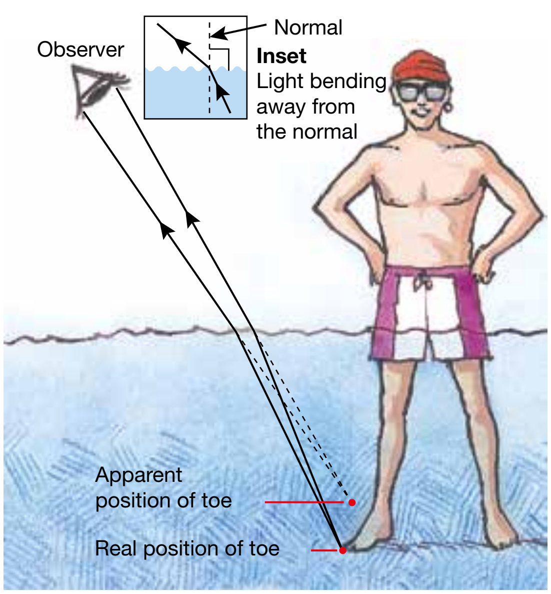
Likewise, when the vehicle drives off the sand onto a hard surface, it changes direction again.

Refraction diagrams

The best way to describe which way the light bends is to draw a line at right angles to the boundary. This line is called the normal. When light speeds up, as it does when it passes from water into air, it bends *away* from the normal. When light slows down, as it does when it passes from air into water, it bends *towards* the normal.

The light coming from the swimmer's legs in the photograph below bends away from the normal as it emerges from the water into the air. The light arrives at the eyes of an observer as if it were coming from a different direction. The diagram below shows what happens to two rays of light coming from one of the swimmer's toes. To the observer, the rays appear to be coming from a point higher than the real position of the toe. The amount of bending depends on the angle at which the light crosses the boundary.



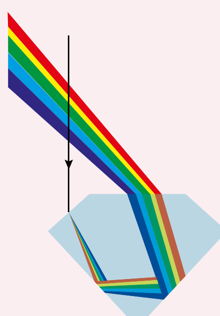


Short legs? Not really.

HOW ABOUT THAT!

Why diamonds sparkle

A diamond can sparkle with coloured light, each of its surfaces producing a dazzling display. Diamond is the most optically dense, naturally occurring material on Earth. This means that light entering a diamond through each of its facets (or geometrically cut sides) is refracted by a huge angle, causing light inside the gemstone to bounce back and forth several times before it strikes a facet with an angle straight enough to escape. Because the light has travelled so far, the spectrum of colours that make up light have dispersed (or separated) so significantly that a stunning display of colours is produced.



INVESTIGATION 4.7

Floating coins

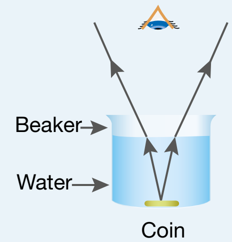
AIM: To investigate the effect of refraction on the image of a submerged object

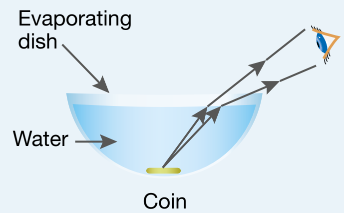
You will need:

2 beakers
evaporating dish
coin

- Place a coin at the bottom of an empty beaker and look at it from above while your partner slowly adds water from another beaker.
- Place the coin in the centre of an evaporating dish and move back just far enough so you can no longer see the coin. Remain in this position while your partner slowly adds water to the dish.
- Make a copy of the diagrams at right. Use dotted lines to extend back the rays shown entering the observer's eye to see where they seem to be coming from. This enables you to locate the centre of the image of the coin.

The image of the coin is not in the same place as the actual coin.





Discussion

1. How does the position of the coin appear to change while the water is being added?
2. Which other feature of the coin appears to change?
3. What appears to happen to the coin as water is added to the evaporating dish?
4. Is the image of the coin above or below the actual coin?

INVESTIGATION 4.8

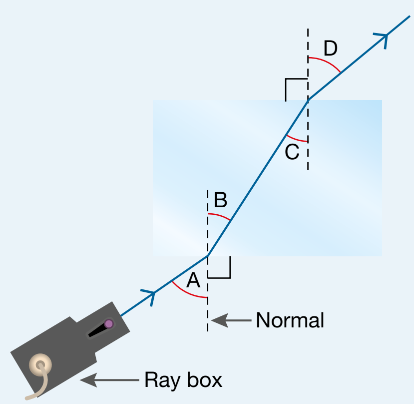
Predicting the way light bends

AIM: To investigate how light is refracted when it enters and leaves a material

You will need:

transparent rectangular prism
pencil
ray box
ruler
12 V DC power supply
protractor

- Place the ray box on the edge of your notebook page and connect it to the power supply.
- Position the ray box so that a single light ray strikes the edge of the rectangular prism as shown.
- Trace around the prism. Use arrows to mark the points where the ray enters and exits the block.
- Remove the prism and turn off the ray box.
- Use a ruler to draw the normal line as shown in the diagram.
- Using the ruler again, draw the ray as it enters the prism, passes through it and exits the other side.
- Measure angles A, B, C and D. Record the measurements in a table.
- Repeat the experiment three more times. Change angle A each time by positioning the ray box at a slightly different angle and record angles A–D.



Discussion

1. Two of the angles can be labelled 'angle of incidence' and two can be labelled 'angle of refraction'. Which of A, B, C and D are angles of refraction and which are angles of incidence?

2. Compare angle A with angle B. What do you notice about the size of A compared with B?
3. Compare angle C with angle D. What do you notice about the size of C compared with D?
   Light travels more slowly in the rectangular block than in air. In general, the more dense the transparent material, the slower light will travel through it.
4. Complete the following conclusion:
   (a) When light travels from one medium to another and slows down, the refracted angle is ____________________ than the incident angle.
   (b) When light travels from one medium to another and speeds up, the refracted angle is _____________________ than the incident angle.

INVESTIGATION 4.9

Focusing on light

AIM: To investigate how biconvex lenses refract rays of light

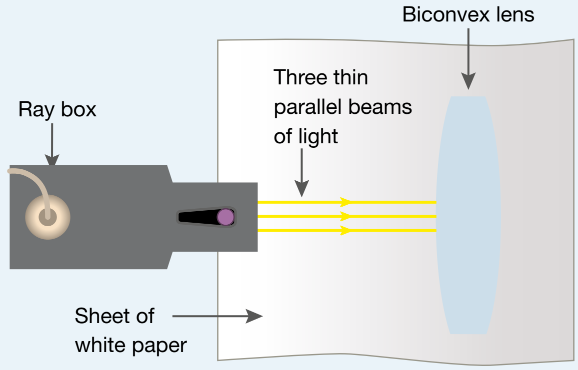
You will need:

ray box kit
12 V DC power supply
sheet of white paper
ruler and fine pencil

- Connect the ray box to the power supply and place it on a page of your notebook.

Part A: Biconvex lenses

- Place the thinner of the two biconvex lenses in the kit on the page and trace out its shape. Project three thin parallel beams of white light towards the lens.
- Trace the paths of the light rays as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light rays through the lens.
- Replace the thin biconvex lens with a thicker one and repeat the previous steps.



Part B: Biconcave lenses

- Place the thinner of the two biconcave lenses on your notebook page and trace out its shape.
- Trace the path of each of the three thin light beams as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light beams through the lens.

Discussion

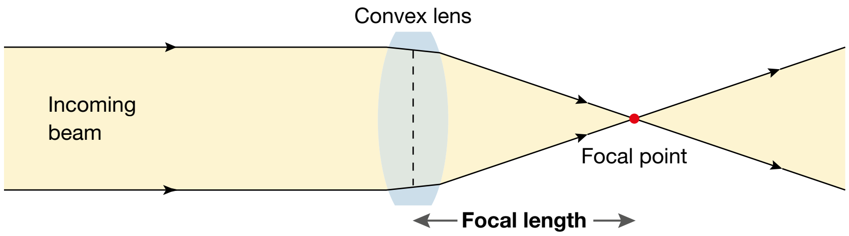
1. Determine the focal length (distance from the focal point to the centre of the lens) for each lens.
2. Identify which lens bends light more, the thin one or the thicker one.
3. Explain why the middle light ray does not bend.
4. Identify how many times each of the other rays bend before arriving at the focal point.
5. Do the diverging rays come to a focus?
6. Do the diverging rays appear to be coming from the same direction? Use dotted lines on your diagram to check.

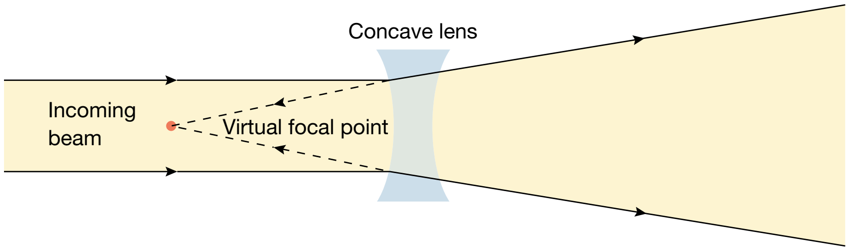
4.3.3 Lenses at work

The bending of light through transparent materials can be used to produce some interesting and useful effects. Lenses are useful because they bend light in a predictable way and can change the way we see the world. The type of **image** produced by a lens depends on the shape of the lens.

Two basic shapes

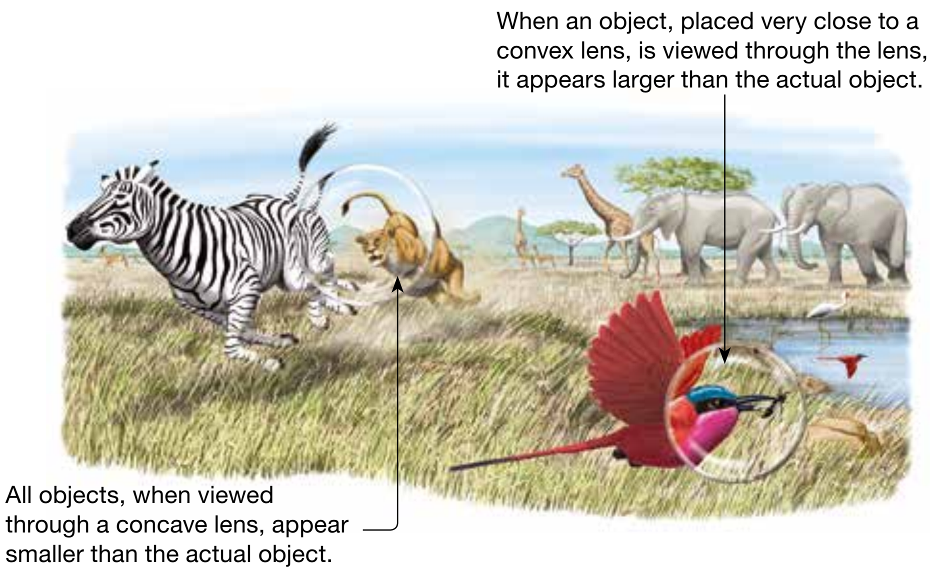
Lenses can be shaped in two basic ways; the ones that curve outwards are called convex lenses. Those that curve inwards are called concave lenses.





Convex lenses are sometimes called **converging lenses**. That's because light rays that pass through them are refracted towards each other so that they meet (converge) at a point. The point where the light rays meet is called the focal point of the lens.

Concave lenses are sometimes called **diverging lenses**. When rays of light pass through these lenses, they refract away (diverge) from each other. Concave lenses have no real focal point, because rays of light do not meet after passing through the lens. However, if you trace the rays back to where they appear to have come from, they do meet at a point, called a 'virtual' focal point.



INVESTIGATION 4.10

Searching for an image

AIM: To investigate the image formed by a biconvex lens

You will need:

candle
matches
jar lid to hold candle
biconvex lens
lens holder
A4 sheet of paper folded in half to act as a screen

- Place the biconvex lens in the lens holder, with the candle about one metre in front of it. Light the candle, and move the screen backwards and forwards on the other side of the lens until a clear image of the flame is visible on it.
- Move the candle towards the lens, stopping every 10 cm or so, while you try to locate the image on the screen. Do not move the candle closer than about 10 cm from the lens. Don't be concerned if you cannot get a clear image on the card when the candle is close to the lens.
- Place the candle 5 cm from the lens. Attempt to find an image on the screen. If you cannot, look through the lens towards the candle, observing the image in the lens.

Discussion

1. Is the image on the screen upright or inverted?
2. How does the image change as the candle is moved closer to the screen?
3. When the candle is close to the lens, can an image be found on the screen?
4. When you look through the lens at the candle, you see an image. Is it upright or inverted? Is it larger or smaller than the real candle?

4.3 Exercise: Remember and think

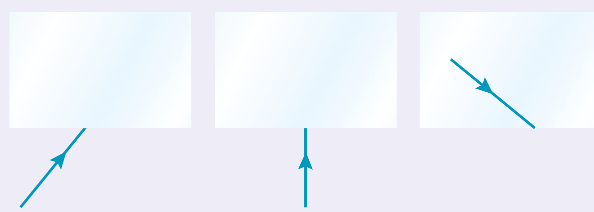
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify**:
   (a) a feature that sound waves and electromagnetic waves have in common.
   (b) a feature that differs between sound waves and electromagnetic waves.
2. **Define** the term 'refraction' and **explain** what causes it.
3. **Identify** the type of lens that causes light rays to:
   (a) diverge
   (b) converge.
4. You cannot usually see light as it travels through air. **Explain** what makes it possible to see beams of light.
5. **Outline** what happens to light when it travels through air and meets:
   (a) a transparent surface
   (b) a translucent surface
   (c) an opaque surface.

Think

6. Copy and complete the light rays in the diagram at right as they move from one medium to another. All the prisms are Perspex and are surrounded by air.



7. Light travels more slowly through diamond than any other transparent material. **Explain** how a jeweller could determine if a piece of diamond is real or fake.
8. **Explain**, with the aid of a diagram, why the image in a convex lens can be upside down.
9. The illustration at right shows a ray of light emerging from still water after it has been reflected from a fish. Should the spear be aimed in front of or behind the image of the fish? Use a diagram to **explain** why.

Calculate

10. The distance between the sun and the Earth is approximately 150 million kilometres. **Calculate** how long sunlight takes to reach Earth.

Investigate

11. Stand a brightly coloured pencil in a glass of water. Make an accurate drawing of how the water distorts the image of the pencil.
12. You can make a microscope by looking through two convex lenses that are placed one behind the other. Experiment with different distances between the two lenses to get the best possible magnification and report on your results.
13. Test your knowledge of the lenses used in common items by completing the **Time out 'Lenses'** interactivity in the Resources tab.
14. Use the **Bend it** interactivity in the Resources tab to test your knowledge of the refraction of light.

learnon RESOURCES — ONLINE ONLY

- **Try out these interactivity:** Time out 'Lenses' (int-1017)
- **Try out these interactivity:** Bend it (int-0673)
- **Complete this digital doc:** Worksheet 4.1: Reflection and scattering of light (doc-12753)
- **Complete this digital doc:** Worksheet 4.2: Curved mirrors (doc-12754)
- **Complete this digital doc:** Worksheet 4.3: Refraction (doc-12755)

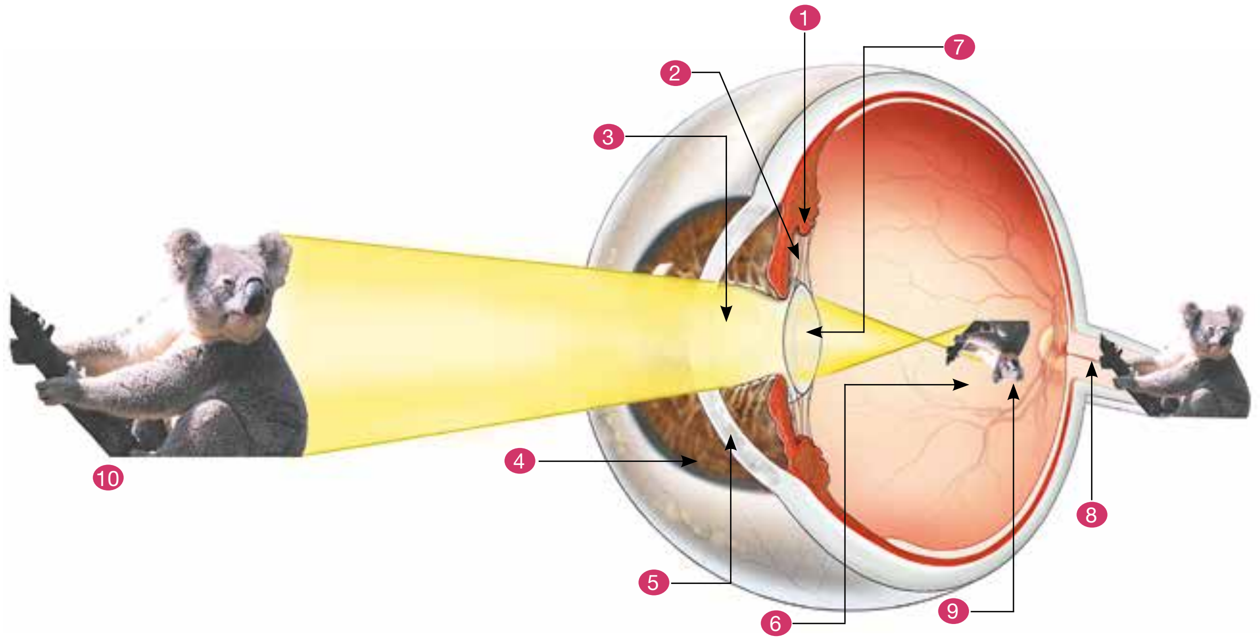
4.4 Colour vision

4.4.1 Vision

Everything that you see is an image! A sharp image of what you are looking at is formed on a 'screen' at the back of your eye. This screen, called the retina, is lined with millions of cells that are sensitive to light. These cells respond to light by sending signals to your brain through the optic nerve.

The light reflected from your surroundings enters your eye and is refracted as it passes through the outer surface of your eye. This transparent outer surface, called the cornea, is curved so that the light converges towards the lens. Much of the bending of light done by the eye occurs at the cornea.

On its way to the lens, the light travels through a hole in the coloured iris called the pupil. The iris is a ring of muscle that controls the amount of light entering the lens. In a dark room the iris contracts to allow as much of the available light as possible through the pupil. In bright sunlight the iris relaxes, making the pupil small to prevent too much light from entering. The clear, jelly-like lens bends the light further, ensuring that the image formed on the retina is sharp. This image is inverted; however, the brain processes the signals coming from the retina so that you see things the right way up.



1 **Ciliary muscles**
Contract to thin the lens when viewing distant objects.

2 **Suspensory ligaments**
Attach the ciliary muscle to the lens.

3 **Pupil**
The opening through which light travels towards the lens. The iris opens and closes to control its size.

4 **Iris**
The coloured ring of muscle that opens and closes to control the amount of light entering the pupil.

5 **Cornea**
Refracts the incoming light, so that it passes through the pupil towards the lens.

6 **Retina**
The image forms here. The light-sensitive cells detect the brightness and colour of the different parts of the image. This information is sent to the brain through the optic nerve. The image is upside down on the retina. The brain constructs a flnal image that is the right way up.

7 **Lens**
Completes the refracting, so that the rays from each point are focused on the retina.

8 **Optic nerve**
Connects the retina to the brain.

9 **Image**
The image is upside down. If the cornea and lens have worked together to refract the incoming light by just the right amount, the image is clear and sharp.

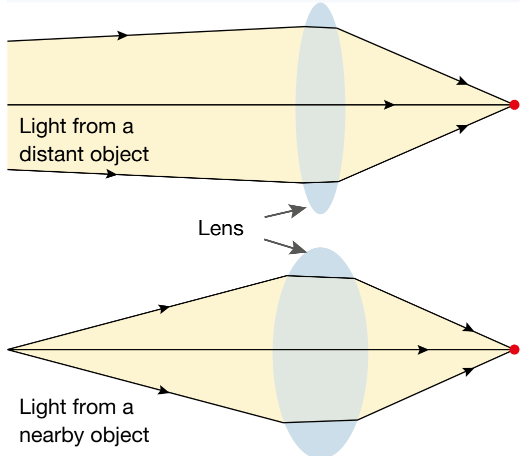
10 **The object**
The object will not be seen unless it is either:

- luminous: that is, emits light itself
- illuminated by the sun or another light source. Light from these sources is reflected from the object.

4.4.2 Getting things in focus

Although most of the bending of light by the eye occurs at the cornea, it is the lens that ensures that the image you see is sharp. The shape of the lens is controlled by the **ciliary muscles**. When you look at distant objects, these muscles are relaxed and the lens is thin. When you look at nearby objects, the ciliary muscles contract. The **suspensory ligaments** become slack, causing the lens to bulge. This action of the lens in obtaining a sharp image on the retina is called **accommodation**.

The light coming from a nearby object needs to be bent more than the light coming from a distant object. The lens in your eye becomes thicker when focusing on nearby objects.



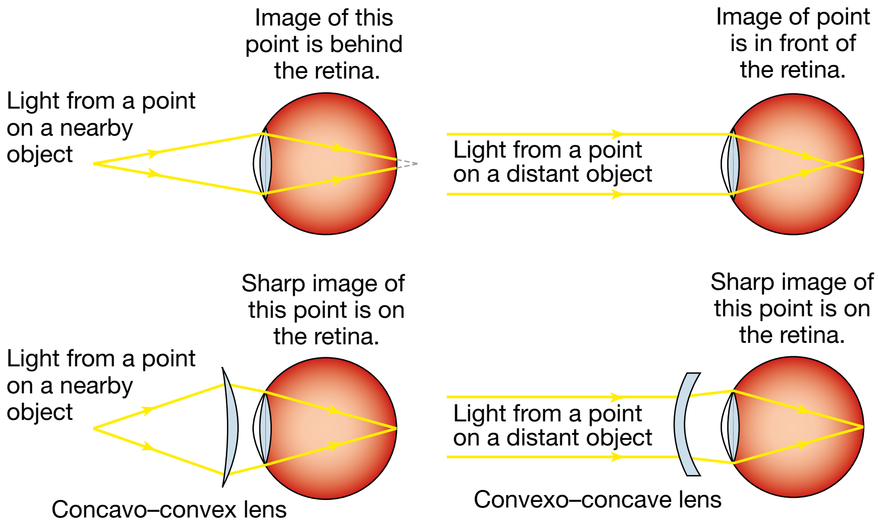
Correcting vision problems

For some people, the cornea and/or the lens of their eye is unable to **focus** a sharp image onto the retina. These people need to wear glasses or contact lenses to correct the problem.

If the cornea and lens bend the light too much, the light rays focus before the retina. People with this condition are short-sighted. They can usually see nearby objects clearly, but cannot focus on distant objects. The problem can be corrected by wearing convexo–concave glasses or contact lenses. The lenses in these glasses **diverge** the light rays a little before entering the eye.

A concavo–convex lens has one side slightly concave and the other slightly convex. The convex side is more curved than the concave side, so it acts like a convex (converging) lens.

A convexo–concave lens has one side slightly convex and the other slightly concave. The concave side is more curved than the convex side, so it acts like a concave (diverging) lens.



Correcting long-sightedness

Correcting short-sightedness

If the cornea and lens do not bend the light enough, the light rays focus at a point past the retina. People with this condition are long-sighted. They can usually see far-away objects clearly, but cannot focus on nearby objects. The problem can be corrected by wearing concavo–convex glasses. The lenses in these glasses converge the light rays a little before entering the eye.

HOW ABOUT THAT!

Insect eyes

Each human eye contains just one biconvex lens. Insects have compound eyes. Each eye contains many lenses. Some types of dragonfly have more than 10 000 lenses in each eye. Each eye can focus light coming from only one direction.

HOW ABOUT THAT!

Cataracts

As the lens becomes less flexible with age, it can become less transparent. Small cloudy spots, called *cataracts*, can develop in parts of the lens. Sometimes, they spread through the whole lens causing blurred vision. In severe cases, cataracts cause blindness as the lens becomes completely opaque.

When cataracts are serious enough to blur vision, the affected lens is surgically removed. It is replaced with a plastic lens. Unlike the original lens, it has a fixed shape and cannot accommodate to focus on both distant and nearby objects. Therefore, people who have had cataracts removed need glasses or contact lenses to compensate for the lack of accommodation.

INVESTIGATION 4.11

Accommodation

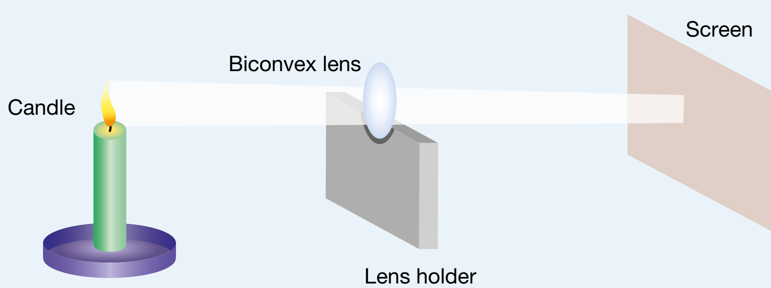
AIM: To model the process of accommodation of the eye

You will need:

candle matches
jar lid to hold candle
ray box kitw
biconvex lens
lens holder
12 V DC power supply
ziplock bag
A4 sheet of paper folded in half to act as a screen

Part A: A rigid lens

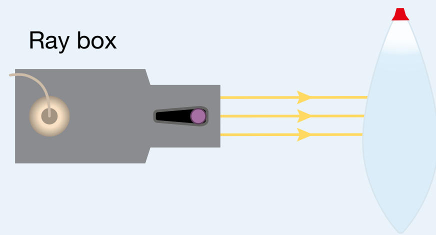
- Dim the room.
- Place the biconvex lens in the lens holder, and position the candle about one metre in front of it. Light the candle, and move the white card backwards and forwards on the other side of the lens until a clear image of the flame is visible on it.
- Move the candle towards the lens, stopping every 10 cm or so, while you try to locate the image on the screen. Do not move the candle closer than about 10 cm from the lens.
- How does the image change as the candle is moved closer to the screen?



Part B: Accommodating

- Fill the ziplock bag with water so that it is almost full and seal firmly.
- Set up a ray box to produce parallel rays of light.

- Shine the light rays through the ziplock bag held vertically and sketch the path of the light rays as they travel from the ray box through the bag and onto the other side. The ray box may need to be elevated by placing it over a textbook so that the light rays pass through the centre of the bag.
- Now pull the ziplock bag tightly from either side and once again sketch the path of the light rays.

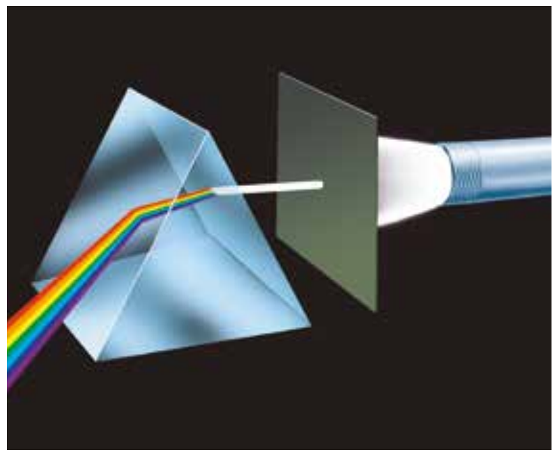


Discussion

1. Describe the problem with using a rigid lens to produce images of objects at differing distances.
2. Define the term ‘accommodation’.
3. Refer to your results in part B of this experiment to explain how the eye can accommodate images of different distances.
4. Discuss the benefits and limitations of modelling accommodation by the eye through this activity.

4.4.3 The visible spectrum

In 1666, Sir Isaac Newton discovered that white light in fact consists of different colours. Today, this set of colours is called the **visible spectrum** of red, orange, yellow, green, blue, indigo and violet colours.



In his experiments, Newton used a glass triangular prism, similar to the one in the diagram at right. When white light enters a triangular prism at an angle, different colours emerge from the other side of the prism. The separation of white light into its component colours as a result of refraction is called **dispersion**. This occurs because each colour of light has a slightly different speed in glass and is, therefore, refracted at a slightly different angle. In a triangular prism, this difference is enhanced because the white light is refracted twice in the same direction. When white light enters the prism, the different colours are bent by slightly different amounts. When the light emerges back into the air, the different colours are bent by different amounts again.

INVESTIGATION 4.12

Eye dissection

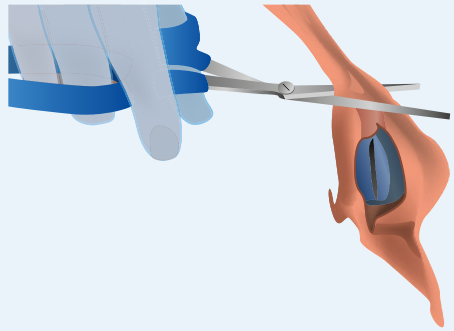
AIM: To examine the inner structure of the mammalian eye and to identify the components involved in vision

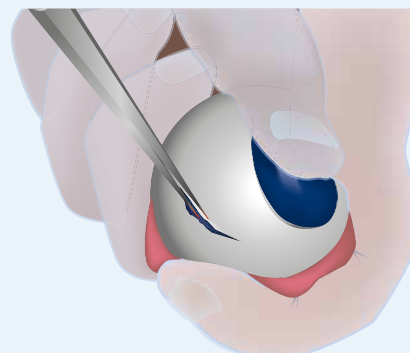
You will need:

sheep or cow’s eye
scalpel
dissecting scissors
newspaper
surgical gloves
cutting board or other surface on which you can cut
soap and detergent for cleaning up

CAUTION: **Take care when using dissecting instruments. Carry them carefully to and from your workbench and be careful not to make contact with sharp ends.**

- Allocate roles to each member of your group based on their skills and interest. One or two students could carry out the dissection, while another student records observations, and draws and labels the specimen. Another student may have a managerial role, reading directions and providing advice.
- Examine the outside of the eye. Draw and label:
  - the sclera, the tough, outer covering of the eyeball
  - fat and muscle surrounding the eye
  - the cornea which was clear when the animal was alive but is now probably cloudy
  - the iris, or coloured part of the eye
  - the pupil, the dark oval in the middle of the iris.
- Cut away the fat and muscle.
- Use the sharp point of a pair of scissors to make an incision on the side of the eye through the thick *sclera*. Then cut around the middle of the eye, cutting the eye in half. You'll end up with two halves; the front half will contain the *cornea* and *lens*.
- Cut away the cornea and locate the *iris* between the cornea and the lens and extract it in one piece. The hole in the centre of the iris, called the *pupil*, should be visible.
- Locate and remove the lens. It should be a transparent, jelly-like lump about the size of a pea. Hold the lens up and look through it at a distant object. Describe what you see.
- Place the lens down on newspaper print and describe the appearance of the print.
- Locate the *retina*, the uppermost layer inside the back of the eye and describe its appearance.
- Locate the position in the retina where the optic nerve commences.
- Draw a labelled diagram of the interior parts of the eye.
- When complete, wrap all tissues and dissecting gloves in the newspaper for disposal.
- Place all dissecting instruments in a basin of detergent for washing.





Discussion

1. Identify the shape of the lens in the eye. Explain why the lens is this shape. You might like to include a diagram.
2. Between the cornea and lens is a transparent liquid called the aqueous humour, and between the lens and the back of the eye is a transparent jelly-like fluid called the vitreous humour. Suggest the function of these two substances.
3. The spot where the nerve cells from the retina are attached to the optic nerve at the back of the eye is called the blind spot. Can you suggest why?
4. The surface under the retina may appear shiny; suggest why. (*Hint:* Think of the appearance of the eyes of a cat when lights are flashed towards it at night.)

4.4.4 How do we see coloured objects?

It's not just a triangular prism that can split white light into separate colours. Coloured objects can separate white light by absorbing some colours and reflecting others.

The colour of an object depends on which parts of the spectrum are reflected towards your eyes.

When white light falls on any opaque surface, some colours are reflected while others are absorbed. A red surface absorbs all of the colours of the spectrum except red. Only red light is reflected. A green substance absorbs all of the colours except green, and a blue substance absorbs all of the colours except blue.

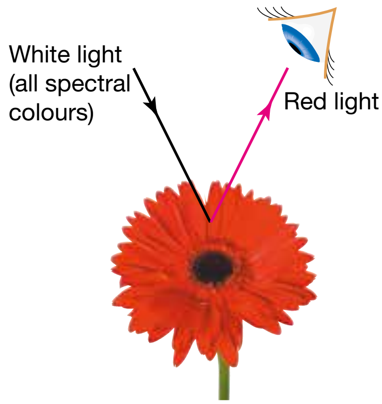
Transparent objects, such as cellophane and coloured glass, split white light by absorbing some colours and allowing others to pass through.

The way we see colours has more to do with our brain than our eye. The human eye has only three kinds of colour-sensitive cells — blue, green and red. The colour-sensitive cells, called **cones**, are found in the retina. The brain uses the information from the three types of cone to create a multi-coloured image of the world around us.

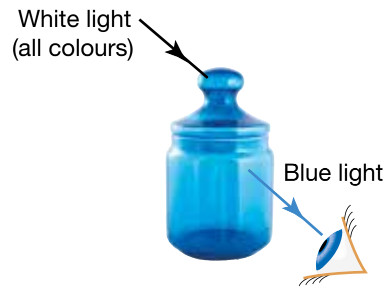
The three colours that our eye is sensitive to (blue, green and red) are called the **primary colours**. Our brain re-creates the rich colours of the world around us by interpreting the response from each of the three types of cone. For example, a red object causes only the red cones to 'fire'. So, we see red. A yellow object, however, causes both red and green cones to 'fire' in equal amounts. Our brain takes this mixture of red and green from the eye and we see it as yellow. In this way, it is possible to create a unique firing pattern for each possible colour.

Colours that are created by equal amounts of 'firing' from two different cones are called secondary colours. The **secondary colours** are yellow, magenta and cyan — all of which can be seen in the diagram below. If all three cones 'fire' equally, we see white light.

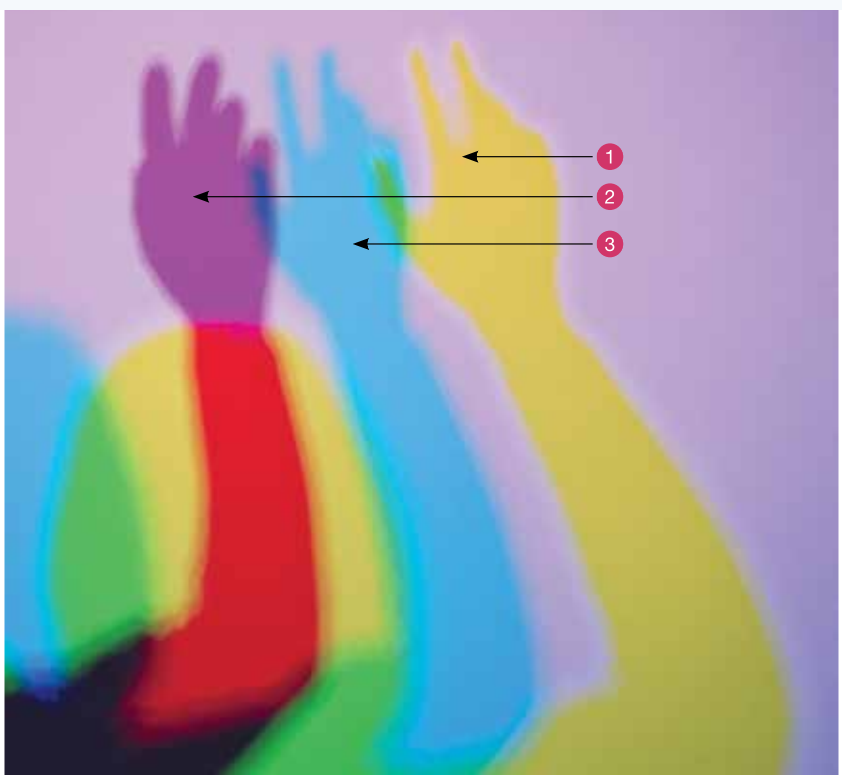
When white light strikes this red flower, all of the colours in the white light, except red, are absorbed. Red light is reflected into our eye and we see a red flower.



When white light shines onto blue glass, all colours, except blue light, are absorbed.
Blue light passes through the glass. If you look through the glass, everything appears blue because only blue light passes through it to reach your eye.



Blue, red and green light are used to illuminate the hands.

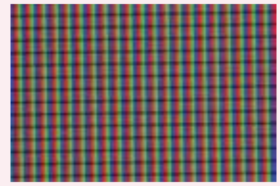


1 **Yellow** This part of the screen receives equal amounts of light from the red and green lamps, but no light from the blue lamp.
2 **Magenta** This part of the screen receives equal amounts of red and blue light, but no green light.
3 **Cyan** This part of the screen receives equal amounts of green and blue light, but no red light.
The three colours mixed together in equal amounts produce white light.

HOW ABOUT THAT!

Colour television

A TV screen can re-create all possible colours by using only the three primary colours. The image on a television screen is made up of thousands of dots of blue, green and red light. These dots are called pixels. By carefully adjusting the brightness of each colour pixel, any colour can be re-created. So, when we view an area of a TV screen where both the green and the red pixels are equally bright, we see yellow.



INVESTIGATION 4.13

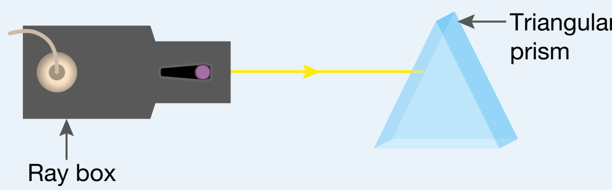
What's in white light?

AIM: To demonstrate that white light consists of a visible spectrum

You will need:

torch
triangular glass prisms
sheet of white A4 paper
ray box
12 V DC power supply

- Place the triangular glass prism about 10 cm in front of the beam of light from a torch.
- Use the sheet of white paper as a screen just behind the prism and move the prism around until you can see a band of different colours on the screen. Once you have found the band, move the screen away from the prism and try to project it onto a wall.
- Connect the ray box to the power supply. Place the sheet of white paper in front of the ray box. Project a single thin beam of light towards the triangular prism as shown in the drawing at right.
- Move the triangular prism as necessary until a band of colours is produced.
- Use a second prism to try to merge the colours into a beam of white light on the screen.



Discussion

1. What colours could you see when the white light was separated into different colours by the prism?
2. Which colour is bent the most by the prism? Which colour is bent the least?
3. Suggest how the glass in the prism managed to separate the colours.
4. Draw a diagram to show how a second prism can be used to merge the colours separated by the first prism.

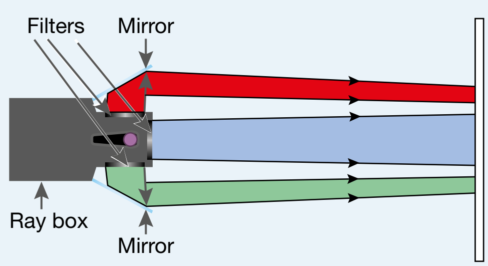
INVESTIGATION 4.14

Adding colours

AIM: To investigate the result of combining colours

You will need:

ray box kit, including coloured filters
12 V DC power supply
white surface to use as a screen



- Place the blue, green and red filters in the slide slots provided on the ray box. This investigation works best if you put the blue filter in the forward-facing slide slot.
- Use the ray box in a darkened room to produce separate red, green and blue patches on the screen.
- Move the mirrors of the ray box to create areas where the different primary colours overlap.
- Replace the blue, green and red filters with yellow, magenta and cyan filters and record your results to the table.

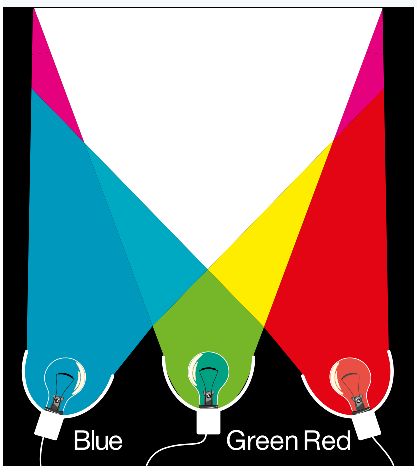
Discussion

1. Copy the table at right and record the possible combinations of primary colours and the resulting secondary colours observed on the screen.
2. Were the results obtained when each set of colours were combined expected? Explain why or why not.

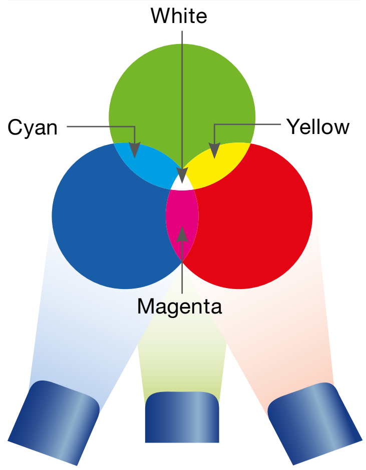
Adding colours

Colours combined	Colour observed on screen
Red + green + blue	
Red + green	
Red + blue	
Green + blue	
Yellow + magenta + cyan	

Blue, green and red light are combined here to produce white light. If someone were to stand in the way of the lights, they would be blocking blue light on one region of the wall, red on another and green on another. This creates yellow, magenta and cyan.



The primary and secondary colours



INVESTIGATION 4.15

Subtracting colours with filters

AIM: To investigate the result of colours being filtered out

You will need:

ray box
12 V DC power supply
red, green, blue, yellow, magenta and cyan filters
white surface to use as a screen

- Make a copy of the table on the next page in which you can record your predictions and observations.
- Connect the ray box to the power supply and darken the room.
- Project a beam towards the screen and place the magenta filter in the ray box. Predict the colour that you would expect to observe on the screen if you place a red filter in front of the magenta filter. Test your prediction and record the colour observed in the table.

- Replace the red filter with a green filter and again predict and observe the colour seen on the screen.
- Replace the green filter with a blue filter and yet again predict and observe the colour seen on the screen.
- Remove the blue filter and place both the cyan and yellow filters directly in front of the magenta filter. Make and record your prediction about what you will observe on the screen before you make your observation.
- Use the filters that you have available to complete the table. Add lines to the table if you would like to test other combinations.

Discussion

1. Which primary colours (red, green or blue) are *transmitted* by the:
   (a) magenta filter?
   (b) cyan filter?
   (c) yellow filter?
2. Which primary colour is *subtracted* by the:
   (a) magenta filter?
   (b) cyan filter?
   (c) yellow filter?
3. What colour was produced when the magenta, cyan and yellow filters were all placed in front of the white beam?

Subtracting colours with filters

Filter in ray box	Filter placed in front	Predicted colour on screen	Observed colour on screen
Magenta	Red		
	Green		
	Blue		
	Cyan and yellow		
Cyan	Red		
	Green		
	Blue		
Yellow	Red		
	Green		
	Blue		

HOW ABOUT THAT!

Animal vision

It is widely believed that dogs see their world strictly in black and white. Recent scientific research shows that this is not true. Dogs can see colours, but not as well as humans. They have fewer cones and appear to completely lack cones that detect red light. The result is that dogs see the world in shades of blue, yellow and grey.

Most birds and many insects have good colour vision as it plays an important role for them in finding food, protecting themselves from predators and finding mates so that they can reproduce. Some of them have more than three types of cone cell. Pigeons, for example, have six types of cone cell. Bees have three types of cone, one of which detects ultraviolet radiation, which humans are unable to detect.

It's not all black and white for dogs.

4.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** the two parts of the eye responsible for focusing light.
2. **Identify** whether a short-sighted person has trouble getting a sharp image of distant or near objects.
3. When the eye changes focus from a distant to a near object, **explain** whether the lens of the eye becomes thicker or thinner. Use a diagram to support your answer.
4. **Explain** how the lens changes shape to accommodate objects of different distances.
5. **Identify** the three primary colours detected by cells in the retina.
6. **Explain** how the eye regulates how much light enters it.
7. **Describe** how you can demonstrate that light is actually made up of a mixture of colours.

Think

8. **Explain** why an opaque object appears:
   (a) blue
   (b) white
   (c) black.
9. **Explain** why a section of a stained glass window appears red.
10. **Explain** why it is impossible for a person who has had cataract surgery to accommodate.

Create

11. **Create** a mnemonic, rhyme or song to help you remember the seven colours of the visible spectrum in the correct sequence.
12. **Create** a colour wheel with a disc of cardboard. Colour one third of the cardboard red, another third green and the final third blue. Make a hole in the centre of the cardboard disc so that a pencil can be inserted through it. The pencil needs to fit tightly enough so that the wheel spins when you spin the pencil. What colour do you see when the disc is spun quickly?

Analyse

13. The data in the table on the right shows how the smallest distance (on average) from written text that a clear image can be obtained varies with age.
   (a) Draw a line graph and a curve of best fit to show how the ability to focus changes with age.
   (b) Use your graph to **predict** the smallest distance at which a clear image can be obtained by a person of your age.
   (c) Use your graph to determine from what age the decrease in focusing ability appears to be most rapid.

Age (years)	Distance (cm)
10	7.5
20	9.0
30	12
40	18
50	50
60	125

Investigate

14. Research one of the following topics and produce a poster or ICT presentation to present your findings.
   - How a rainbow is formed and why it is curved
   - What colour blindness is and what causes it
   - Colour vision in animals
   - Why the sky appears blue

learnON RESOURCES — ONLINE ONLY

Explore more with this weblink: Eye dissection

Explore more with this weblink: Colour vision

Complete this digital doc: Worksheet 4.4: The eye (doc-12756)

Complete this digital doc: Worksheet 4.5: Spectrum (doc-12757)

4.5 The communication revolution

Science as a human endeavour

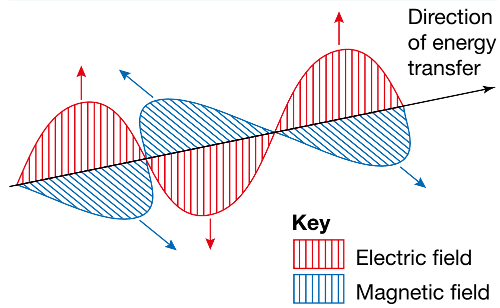
4.5.1 Electromagnetic waves

Light is just one example of electromagnetic waves.

All electromagnetic waves travel through air at 300 000 kilometres per second and can travel through a vacuum. The waves actually consist of pulsing electric and magnetic fields. These fields are generated by oscillating electric charges.

Luminous objects, be they human-made, such as compact fluorescent lights, or naturally occurring like stars, cause charged particles (mainly electrons) to be accelerated, generating the pulsing magnetic and electric fields which we call electromagnetic waves.

A representation of part of an electromagnetic wave

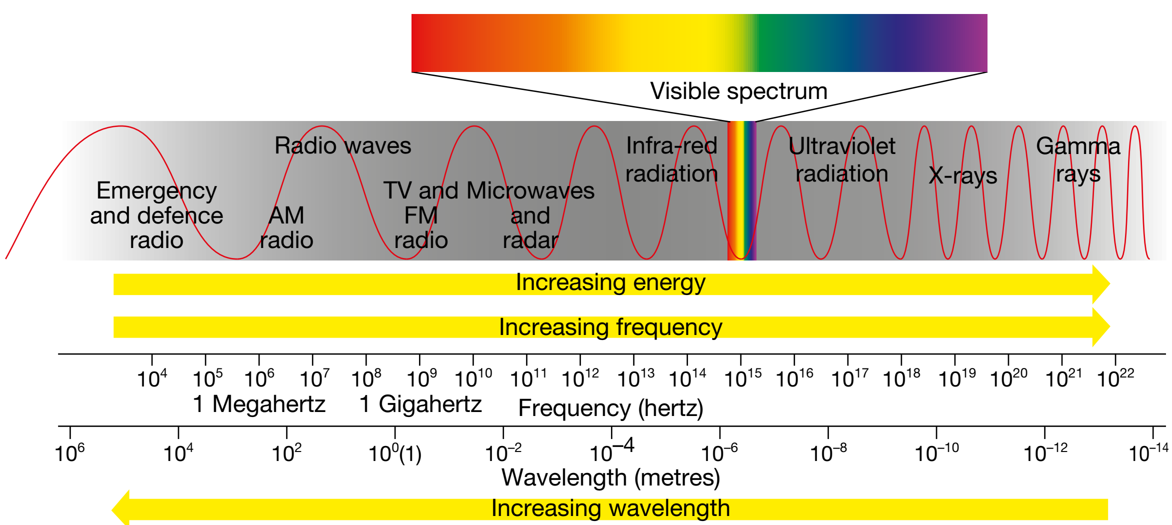


The frequency of electromagnetic waves is a measure of the number of pulses of electric and magnetic fields generated per second. The wavelength is the distance between adjacent crests or troughs in the electric or magnetic fields. The electric and magnetic fields pulse at right angles to the direction of motion of the wave.

Light is not the only example of electromagnetic waves. Ultraviolet light, X-rays and radio waves are all examples of energy carried in the form of electromagnetic waves. Electromagnetic 'radiation' is the term often used to describe these energy forms because like heat energy, their energy can be transferred or radiated through vacant space, without the need for a medium.

4.5.2 The electromagnetic spectrum

Light, X-rays and radio waves are all examples of electromagnetic radiation but they are quite different. X-rays can penetrate the body to provide a bone scan and radio waves can carry communication from radio stations. Each type of electromagnetic radiation exists as an electromagnetic wave with a specific frequency range that matches the frequency of oscillating electric charges which produced them. The entire range of electromagnetic radiation is called the electromagnetic spectrum and is illustrated below. Higher frequency radiation in the electromagnetic spectrum, namely X-rays and gamma rays, carry higher energy intensity and hence can penetrate objects, including body tissues. Gamma rays are used in radiotherapy to attack cancerous cells in tumours.



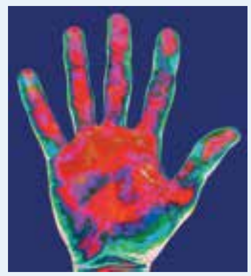
Ultraviolet (UV) light is invisible to the eye. UV light has a higher frequency than visible light and so has a greater energy intensity that causes certain materials to glow or fluoresce. The energy of UV light excites the molecules in these materials to emit visible light. For example, ultraviolet beads change colour in the presence of UV light. They are normally opaque and colourless but change to bright colours upon exposure to UV light.

Ultraviolet radiation

Like infra-red radiation, ultraviolet radiation is invisible to the human eye. It is more energetic than visible light and as a result can cause chemical changes in many substances, including human skin. Exposure to ultraviolet radiation in sunlight leads to tanning but prolonged exposure can cause sunburn. Some sunscreens contain chemicals that absorb the ultraviolet light before it can damage the surface of your skin. Others, like zinc oxide, block the ultraviolet light. Long-term exposure to the sun's ultraviolet radiation increases your chances of skin cancer. Unfortunately, Australia has one of the highest incidences of skin cancer.

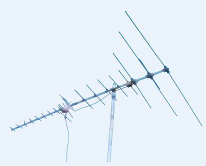
Infra-red radiation

These electromagnetic waves are invisible to the human eye and are emitted by all objects, unless those objects are extremely cold. The amount of infra-red radiation emitted by an object increases as its temperature increases. Remote control devices send out infra-red beams which are detected by receivers with garage doors, TVs and DVD players. Infra-red cameras are used to detect heat.



Radio waves

These are low in energy intensity and include the electromagnetic waves used in TV, AM and FM radio transmissions, microwave waves used in radar, wireless internet and mobile phone communication. The frequency of these waves causes electrons in the receiving antennas of these devices to vibrate at the same frequency, and results in sound and images being produced.



Visible light

This represents only a very small part of the electromagnetic spectrum and contains all the colours of the rainbow, ranging from red (the lowest frequency) to violet (the highest). Visible light is necessary for vision in humans and for the process of photosynthesis in green plants.

X-rays

These high-energy electromagnetic waves can pass through some opaque materials including body tissues, making them useful for diagnosing internal injuries such as bone fractures. X-rays can also be used to kill cancer cells and analyse the molecular structure of complex chemicals. X-rays are produced when fast-moving electrons give up their energy quickly. In X-ray machines, this happens when the electrons strike a metal target made of tungsten.

Gamma rays

These are the highest frequency and most energetic electromagnetic waves. Like X-rays, they are also very penetrating. Gamma rays can pass through many materials, including metals; hence they are sometimes used to find weaknesses in metals. In fact, a thick layer of lead is required to absorb these rays, preventing them from travelling further. Gamma rays can cause serious damage to living cells but they can also be used to kill cancer cells. Gamma rays are produced when energy is lost from the nucleus of an atom. This can occur during radioactive decay of nuclei or as a result of nuclear reactions. Some of the most distant and hottest stars in our universe give out enormous amounts of gamma radiation.

INVESTIGATION 4.16

UV protection

AIM: To investigate the effectiveness of sunscreen lotions

You will need:

UV colour beads
3 suntan lotions of low-range, mid-range and high-range sun protection factor (SPF)
4 small ziplock bags
4 petri dish containers

- Place a small handful of UV beads into each of the ziplock bags and seal them.
- Apply a low-range SPF lotion over the outside of a ziplock bag and label it with the SPF value.
- Repeat this step with the mid-range and high-range SPF lotions and leave the fourth bag as a control.
- Expose the bags to direct sunlight for 10 minutes.
- Tip the contents of each of the bags into separate petri dishes.
- Describe the colour intensity of each sample or take photographs of each as a record.

Discussion

1. What purpose did the control serve in this experiment?
2. Were the higher SPF lotions more effective in reducing exposure to UV light? Justify your response using your observations.
3. Investigate using secondary sources how sunscreen lotions work to reduce UV exposure.

INVESTIGATION 4.17

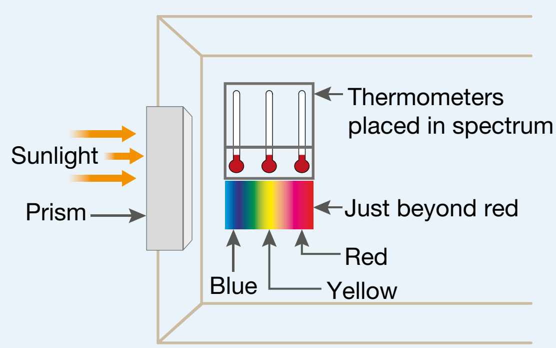
Infra-red radiation

AIM: To detect infra-red radiation

You will need:

glass prism (Note: plastic prisms do not work well for this experiment.)
4 thermometers or temperature probes and a data logger
black marker (water soluble)
scissors and sticky tape
cardboard box (e.g. photocopier paper box)
blank sheet of white paper

- Conduct this experiment on a sunny day.
- If using thermometers, blacken the bulbs of the thermometers to make them energy absorbers.
- Tape the white sheet of paper flat in the bottom of the cardboard box.
- Cut a notch into an edge of the box to mount the prism. The notch should hold the prism snugly, while permitting its rotation about the prism's long axis.



- Place the prism into the notch cut from the box and rotate the prism until the widest possible spectrum appears onto a shaded portion of the sheet of paper at the bottom of the box.
- The side of the box facing the sun may have to be tilted up to produce a sufficiently wide spectrum.
- After the prism is secured in the notch, place the thermometers in the shade and record the ambient air temperature.
- Tape the thermometers into position at the base of the box so that the bulb of a thermometer is placed within the following portions of the spectrum:
  - blue
  - yellow
  - just beyond red.

You may need to cut out a flap along the side of the box to allow the thermometers to sit flat at the base.

- After approximately 10 minutes, exposure to the sun, record the maximum temperature reached by each of the thermometers.
- Calculate the temperature rise at each position in the spectrum and record all your data in a suitable table. Compare your results with other groups.

Discussion

1. Was there a trend in the temperature readings? Was this trend consistent with the results obtained from other groups?
2. Account for your findings.
3. Evaluate the effectiveness of this procedure and your findings. Suggest any improvements that could be made.
4. Why was Herschel's experiment such an important one in our understanding of the electromagnetic spectrum?

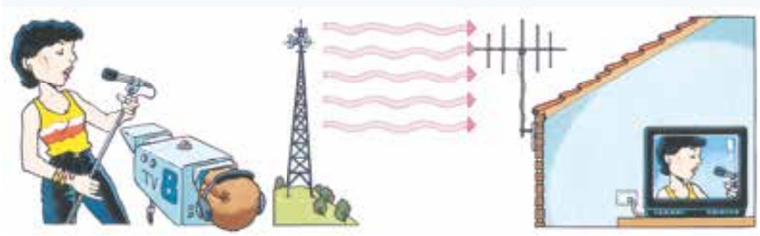
Sir Frederick William Herschel discovered the existence of infra-red light in 1800 by passing sunlight through a glass **prism**, causing it to be dispersed into a spectrum. Just beyond the red end of the spectrum he detected the greatest amount of heat of the visible colours that make up sunlight. Herschel was interested in measuring the amount of heat and realised that there must be another, invisible type of light beyond red in the spectrum.

4.5.3 We're on the air

Many of the devices we use today to communicate, including radios, TVs and mobile phones rely on radio waves. Radio waves were discovered by Heinrich Hertz in 1887 and were first used by Italian scientist Guglielmo Marconi to transmit a message across the Atlantic in 1901.

Radio waves are emitted naturally by stars. They can also be produced artificially when electrons in a metal rod are made to oscillate rapidly. This metal rod is called a **transmitting antenna** or transmitter. These vibrations cause radio waves to travel through the air at the typical speed for an electromagnetic wave; 300 000 kilometres per second. The radio waves can be detected by a receiving antenna, which is a metal rod just like the transmitter. The radio waves cause electrons in the receiving antenna to oscillate rapidly, producing an electrical signal in it. The process of using radio waves to transmit either sound or television pictures is illustrated at right.

Using radio waves to transmit sound and pictures



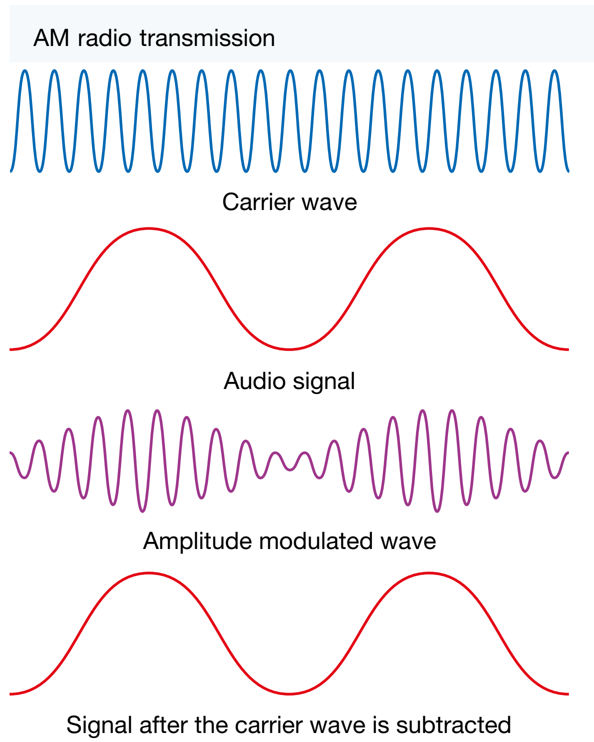
AM radio

Each AM radio station is allocated a particular frequency of radio wave through which it transmits sound signals. The sound signal must firstly be changed to an electrical signal. This electrical signal is called an **audio** signal.

The waves on which messages are sent are called **carrier waves**. The audio signal is added to the carrier wave, producing a modulated wave, as shown in the diagram at right. The receiving antenna of your radio detects the modulated wave. Your radio then 'subtracts' the carrier wave from the signal, leaving just the audio signal. The audio signal is amplified by an audio amplifier inside the radio and sent to speakers. In the speakers, the changing electric current is used to make the surrounding air vibrate to produce sound.

The carrier signals for AM radio stations have frequencies ranging from about 540 kilohertz up to about 1600 kilohertz. When you tune in your radio, you are selecting the frequency of the carrier wave that you wish to receive. For example, if you tune to ABC Local Radio Sydney, you are selecting the carrier wave with a frequency of 702 kilohertz.

AM stands for amplitude modulation, and the diagram at right shows why: the audio signal changes the **amplitude** of the carrier wave.

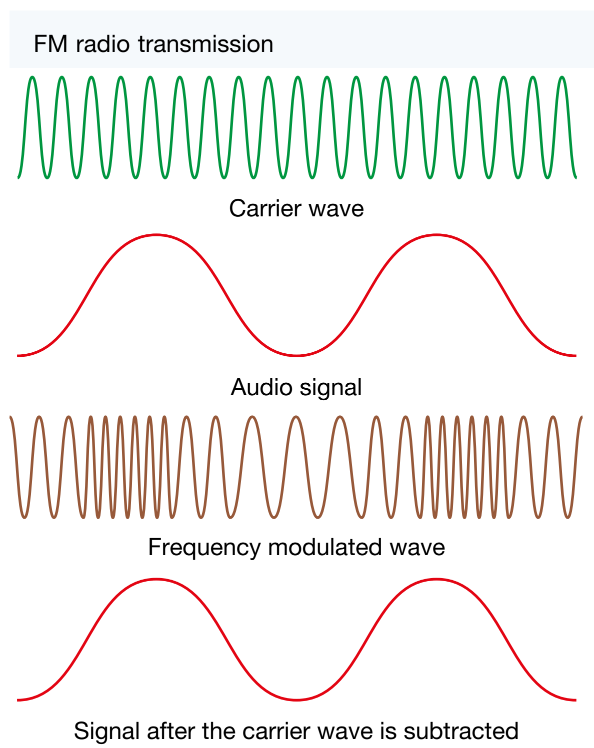


FM radio

Like AM radio stations, each FM radio station has its own carrier wave frequency. However, the carrier frequencies are much greater — between 88 megahertz and 108 megahertz (1 megahertz equals 1 million hertz). The other major difference between AM and FM radio is the way that the audio signal is carried on the carrier wave. Instead of adding the audio signal to the carrier wave and changing its amplitude, the audio signal changes the **frequency** of the carrier wave as shown in the diagram at right. FM stands for frequency modulation.

As with AM radio, when you tune in your radio to FM you are selecting the frequency of the carrier wave that you wish to receive. For example, if you tune to 2 Day FM in Sydney, you are selecting the carrier wave with a frequency of 104.1 megahertz.

FM radio waves are affected less by electrical interference than AM radio waves and therefore provide a higher quality transmission of sound. However, they have a shorter range than AM waves.



Television

Television signals are transmitted on two separate carrier waves. The visual signal is added onto one carrier wave using amplitude modulation. The audio signal is carried on a separate carrier wave using frequency modulation. When you tune your television set to a particular channel, you are selecting the visual and audio carrier waves that you wish to receive. Your television set then completes the task of removing the carrier waves and translating the signals sent into a picture and sound. This is quite a complex task, as you might imagine!

INVESTIGATION 4.18

AM and FM radio

AIM: To compare the reception of AM and FM radio under different conditions

You will need:

a portable radio

- Tune the radio to an AM station of your choice.
- Plan a path through the school that will take you through at least 5 different locations; e.g. classroom → corridor → undercover courtyard → playground → hall.
- At each different location, observe and record the quality of reception as good, medium or poor and record this information in a suitable table.
- Repeat these steps while listening to an FM station of your choice at the same volume level.

Discussion

1. For which station was the reception generally poorer, AM or FM? Were there any 'blackspots'?
2. Account for the locations in the school with the poorest reception in terms of the structures around you.
3. Investigate using secondary sources whether AM or FM radio reception is more likely to be affected by interference and why. Is this research consistent with your findings?

Digital communication

Australian television and radio recently moved from the broadcast of an analogue signal to a digital transmission. While digital transmission has allowed each TV station to broadcast a greater number of programs, what's the difference between digital and analogue transmission?

The radio waves carrying the audio transmission described earlier are examples of analogue signals. Analogue quantities vary continuously over time just as the amplitude and frequencies of AM and FM radio vary. Digital signals on the other hand are non-continuous. They consist of a series of 'on' and 'off' pulses, each representing a particular signal strength or value. The digital value at any particular time is generated using a binary code of 0s (representing off) and 1s (representing on) as shown in the table at right.

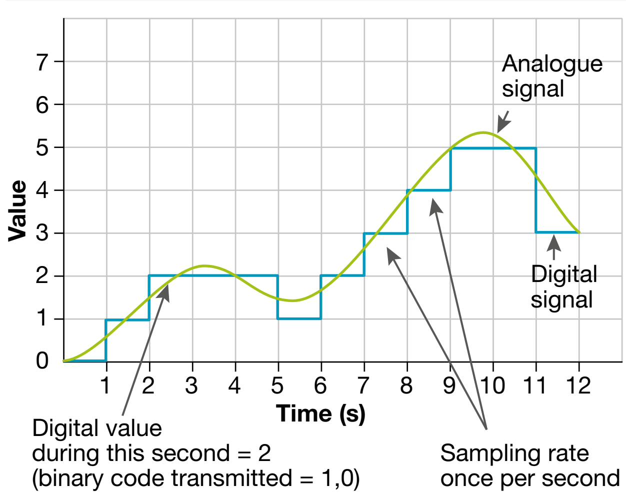
The process of converting the original analogue signal into a series of digital values is called sampling. In 8-bit processing, the amplitude of an analogue wave at any given point in time is converted to a number value on a scale from 0 to 256 (or 2^8). The sampling rate of a signal, on the other hand, determines how frequently the amplitude of an analogue audio or video wave is recorded.

A digital signal is encoded from the original analogue wave and is then transmitted as a binary sequence representing each of the samples taken. A decoding device then reconstructs the amplitude of the analogue wave. You will notice in the diagram at right that the digitised signal has lost some of the sensitivity of the analogue wave. To increase the accuracy of a

The binary code for the first 10 decimal values

Decimal value	Binary code
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010

An analogue vs a digital signal



digital signal, the sampling rate can be increased. Audio signals are generally sampled 40 000 times per second while video signals are sampled more than 13 million times per second.

Another strategy employed is to increase the sensitivity of the digital scale used. Digital technology commonly utilises 14-bit processing (providing a scale with 2^{14} or 16 384 levels), 32-bit (2^{32} levels) or even 64-bit (2^{64} levels) processing.

Analogue or digital — smooth or in bits

You can read the time from an analogue watch with hands that continuously rotate, or from a digital watch with LEDs (light-emitting diodes) or liquid crystals that simply turn off and on.

All physical quantities like time, speed, weight and pH can be represented in analogue or digital form. Likewise, invisible waves like sound and radio waves can be transmitted in analogue or digital form.

- Analogue forms change smoothly if the quantity being measured changes smoothly.
- Digital forms display or transmit quantities as a limited series of numbers or pulses. Digital devices are usually electronic. Their displays are made from devices that can only ever be ‘on’ or ‘off’. For example, each number display of a digital measuring device is made up of seven LEDs/LCDs, each of which can be either ‘on’ or ‘off’. The arrangement of the seven LEDs/LCDs allows all of the numbers from 0 to 9 to be displayed.

An analogue watch represents time as a quantity that changes smoothly.

A digital watch represents time as a quantity that changes in ‘bits’.

Each number in this digital display is made up of seven LEDs, each of which can be either ‘on’ or ‘off’.

4.5.4 What’s the advantage?

Both analogue and digital television signals fade away as they travel through the air. Like all other waves, the energy they carry spreads out. So, as they travel over distance their intensity, or strength, decreases. As the continuous analogue signal becomes weaker, any background radiation and signals from other sources have a greater effect on the amplitude of the wave. It becomes distorted. The result is a fuzzy picture and poor quality sound. Because digital signals consist only of ‘on’ or ‘off’ pulses, background radiation and signals from other sources cannot interfere with them — even as they become weaker. The rapidly pulsating signals are still either ‘on’ or ‘off’ until the ‘on’ signals have faded away to nothing.

As a result, digital television has several advantages over analogue television. It provides:

- sharper images and ‘ghost free’ reception
- widescreen pictures
- better quality sound
- capability of ‘surround’ sound
- access to the internet and email
- capability of interactive television, allowing the viewer to see different camera views or even different programs on the same channel.

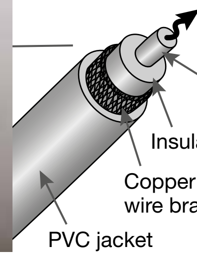
4.5.5 Communication highways

Digital communication has enhanced the quality and capacity of audio and video transmitted to consumers, but the communication revolution also involves developing new technologies to carry this digital signal.

The electrical way

The **coaxial cable** was designed during World War II to improve the speed of communications. The first major coaxial cable in Australia was laid between Sydney, Melbourne and Canberra in 1962. Coaxial cables can simultaneously transmit many more telephone calls and television signals than the copper cables which were previously used.

Many coaxial cables can be bundled together and buried underground or laid on the ocean floor. Coaxial cables can carry television signals as well as telephone calls and facsimile messages.



A coaxial cable consists of a conducting wire at the centre that can carry an analogue or a digital signal. This central wire is surrounded by an insulating material and an outer conductor, usually of a copper or aluminium braided cylinder, which acts as a shield to minimise electrical and radio frequency interference between adjacent cables. The cable is then encased in a protective PVC jacket. Most Australian coaxial cables contain four, six or twelve tubes and are buried under the ground or laid on the ocean floor.

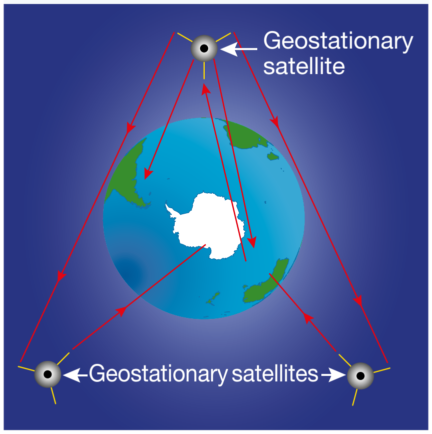
Wireless technology

Analogue and digital television, wireless broadband and mobile phone calls can all be transmitted over long distances using high frequency radio waves, also called **microwaves**. Microwaves range in frequency from about 0.3 GHz to 300 GHz and can carry many signals at the same time. However, repeater stations need to be used so that the signal does not fade away before it reaches its destination. Antennas on the repeater stations receive the microwave signals and send them on to the next station. Each repeater tower needs to be within sight of the next one because radio waves, like visible light, travel in straight lines. So, the repeater towers are built in elevated positions wherever possible.

Repeater stations are towers with dish-shaped antennas.

Communications **satellites** also allow high frequency radio waves to be transmitted at the speed of light from continent to continent. In Australia, satellites are used to transmit radio, television and telephone signals between cities and are a particularly important mode of communication for remote areas. Signals are transmitted to a satellite that is in a **geostationary** orbit, meaning that it orbits the Earth once every 24 hours, thus remaining over the same point on Earth at all times. In order for the satellite to orbit at that rate, it must be positioned at an altitude of about 36 000 kilometres above the equator. Dish antennas, such as the ones in the photograph on the following page, are aimed at particular satellites ready to receive signals. The shape of the dish allows for the collection of large amounts of electromagnetic energy, which is then focused towards the central antenna.

A geostationary satellite relays radio signals to other locations in Australia, or to other continents.



These antennas receive signals that have been re-transmitted by a geostationary satellite.

Optic fibres

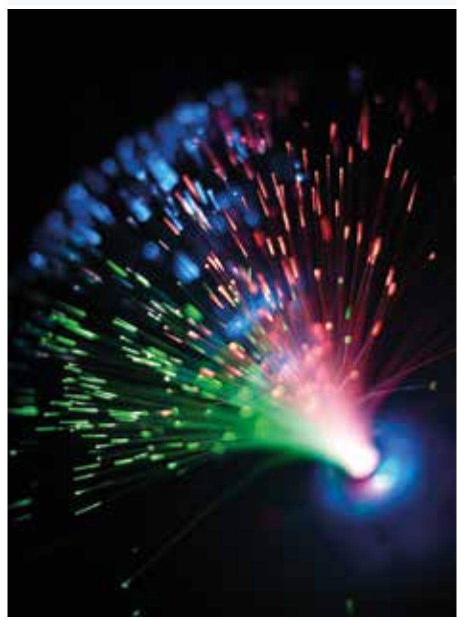
From 2010, the Australian government began rolling out a new super-fast National Broadband Network based on optic fibre technology. While optic fibres currently link major Australian cities and link Australia with other continents, this new network plans to run optic fibres to suburbs, providing broadband speeds that will be 100 times faster than those currently available via conventional wireless or coaxial cable. The table at right demonstrates that optic fibres can also transmit many more messages at one time than coaxial cable or microwaves.

Options for long-distance communication over land

Signal carrier	Number of two-way conversations at once
Copper cable	600
Coaxial cable	2 700
High frequency radio wave	2 000
Optic fibres	30 000

Optic fibres are long, thin, flexible strands of glass. Electrical signals from sources such as a microphone, television camera, computer or facsimile machine are converted into high frequency pulses of light, generally near the infra-red range, which carry a digital signal through the optic fibre. The light pulses received at the other end are converted back into electrical signals that can be fed into speakers, televisions, computers or fax machines. The messages can also be re-transmitted as microwaves if necessary.

Optic fibres use total internal reflection to transmit light pulses.



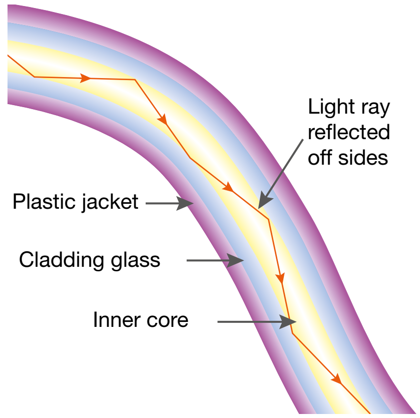
The idea of using visible light to transmit messages over long distances was not feasible until the invention of the laser in 1958. A laser produces an intense beam of light of one pure colour. As the beam travels through the optic fibre, the glass absorbs some of the light energy. Repeaters are needed every 35 to 55 kilometres along the optic fibre cables to amplify the signal. The laser light loses energy less quickly than normal light would, because a laser beam disperses very little.

Optic fibres can be laid under the ground or under water. They are smaller, lighter, more flexible and cheaper than coaxial cables previously used for long-distance telephone, radio and television communication, and the light pulses are not affected by interference from radio waves, so there is no ‘static’.

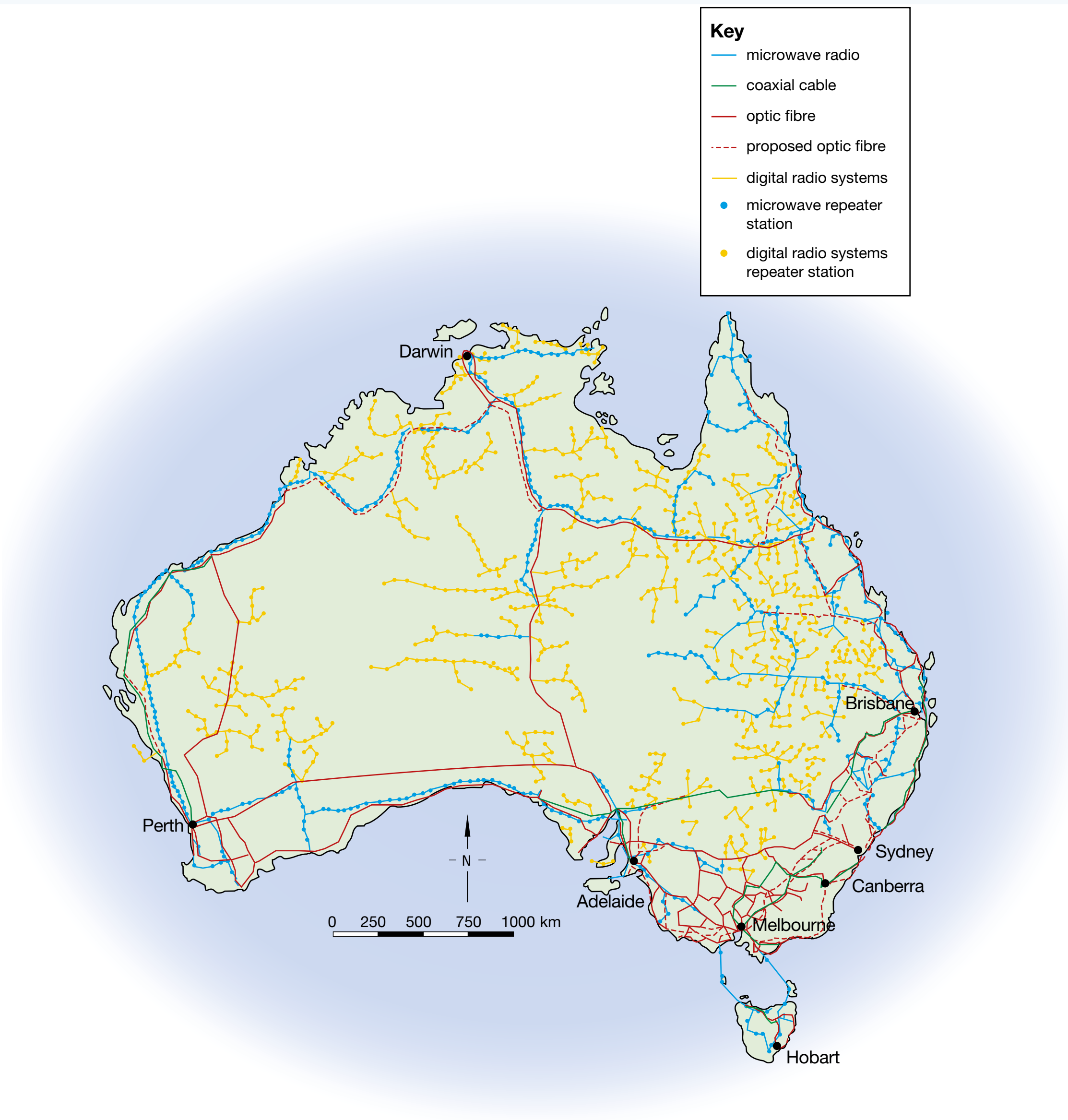
Optic fibres — how they work

The glass in optic fibres is made so that light is unable to escape from the glass. This is achieved by covering the glass with a cladding of denser glass or plastic. As light travels from the inner glass core to the denser cladding, it bends (refracts) so much that, instead of leaving the glass, it is reflected back into it. This process is called **total internal reflection**. The diagram shows how total internal reflection occurs in an optic fibre. Even if the fibre is bent a little, the light is 'trapped' inside by total internal reflection.

Total internal reflection in an optic fibre



Australia's existing long-distance communication network prior to the optic fibre broadband rollout



INVESTIGATION 4.19

Total internal reflection

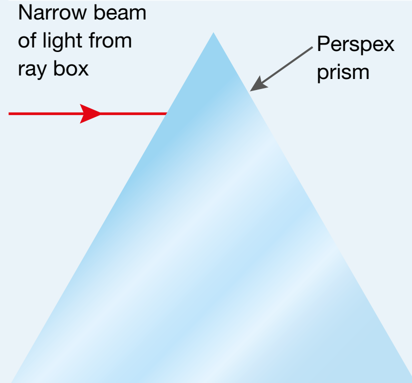
AIM: To observe total internal reflection of light in a Perspex prism

You will need:

ray box kit
12 V DC power supply
Perspex triangular prism

- Connect the ray box to the power supply. Place the ray box over a page of your notebook. Use one of the black plastic slides in the ray box kit to produce a single thin beam of light which is clearly visible on the white paper.
- Place a Perspex triangular prism on your notebook and direct the thin beam of light towards it as shown in the diagram at right. Observe the beam as it passes through the prism.
- Turn the prism slightly anticlockwise, closely observing the thin light beam as it travels from the Perspex prism back into the air. Continue to turn the prism until the beam no longer emerges from the prism.

Observe the beam of light as it passes through the prism.



Discussion

1. Describe what happens to the thin light beam as it passes from air into the Perspex prism and back into the air.
2. Outline what happens to the beam of light when it no longer emerges from the prism.
3. Draw a series of two or three diagrams showing how the path taken by the beam of light changed as you turned the prism.

INVESTIGATION 4.20

Optic fibres

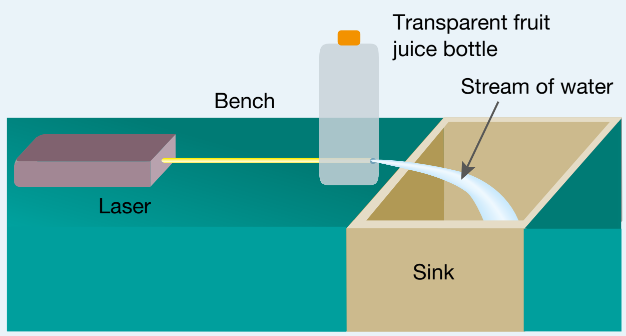
AIM: To investigate the principle utilised in optic fibres

This investigation is carried out as a teacher demonstration to minimise the risks associated with the use of lasers.

You will need:

transparent 2–3 L fruit juice bottle
large nail
laser (class 1)
demonstration optical fibre cable or light pipe

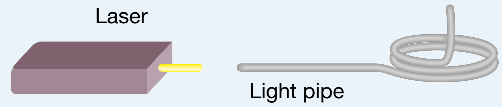
- Use the nail to poke a narrow 5 mm hole into the front of a fruit juice bottle approximately 5 cm from the bottom.
- Darken the room.
- Fill the container to the top with water and position it on the edge of a sink so that a thin stream of water flows from the container into the sink.



CAUTION: Class 1 and class 2 lasers have a relatively low power output and so are safe for classroom use under direct supervision of the teacher. Laser beams should not be pointed towards others in the room because of the sensitivity of the retina of the eye. Ensure that those viewing this demonstration are positioned on either side of the stream of water to eliminate the possibility of the laser beam being directed towards them.

- Direct a laser beam into the bottle and out through the centre of the stream of water.
- Describe the path of the laser beam.

- Shine a laser beam down a length of ‘light pipe’ or loop of optic fibre. Describe your observations.



Discussion

1. Explain why the laser beam took the path of light observed in these demonstrations.
2. Compare the speed of light in air to that in water or the material making up the optic fibre core. Explain how these demonstrations rely on the difference in the speed of light through these media.

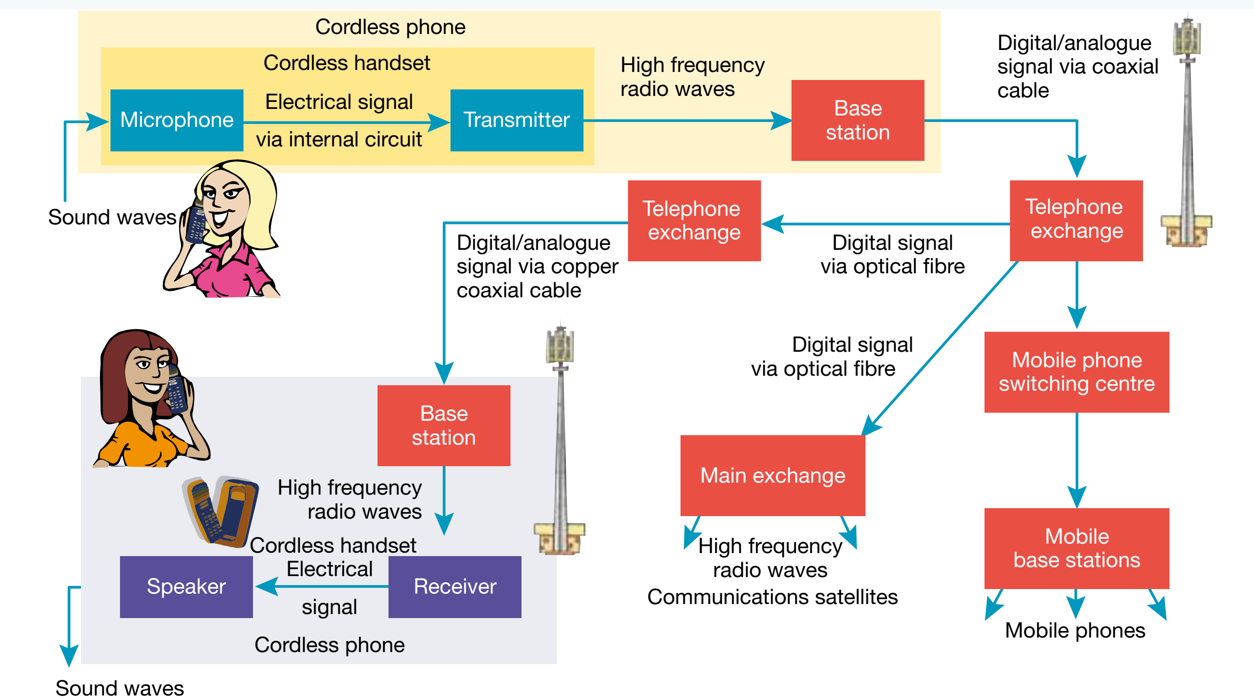
4.5.6 Phone a friend

The landline

Alexander Graham Bell is often credited with the invention of the telephone in 1876 although, like many areas of science, several of Bell’s contemporaries, including Thomas Edison, contributed significantly to the early development of this technology. Australia’s first telephone service, in Melbourne, was launched in 1879. Today, telephones send and receive electric signals over a complex network of coaxial cables that link urban and rural areas throughout Australia. More recently, optic fibres have been incorporated into the network, linking telephone exchanges.

Modern telephones are often cordless, with digital phones increasingly replacing earlier analogue technology. A simple phone call involves quite a bit of technology. To begin with, sound waves from the caller are first converted to an electrical signal by the microphone in the handset. The electrical signal is analogue or digital, depending on the type of telephone. A transmitter in the handset generates radio waves of a specific frequency (in the microwave range) which are detected by a receiver in the phone’s base station. An electrical signal is transmitted from the base station of your phone via copper coaxial cables to the telephone exchange in the phone network. The various telephone exchanges are connected by optic fibre, so electrical signals are converted to digital pulses of light or to high frequency radio waves if the call is to be routed to the mobile phone or satellite network. From the telephone exchange the phone call is once again converted to an electrical signal, and travels to the base station of the receiver’s phone. There it is transformed to a radio wave which is received by the handset and converted by a speaker to a sound wave again.

A landline is part of the communications network.



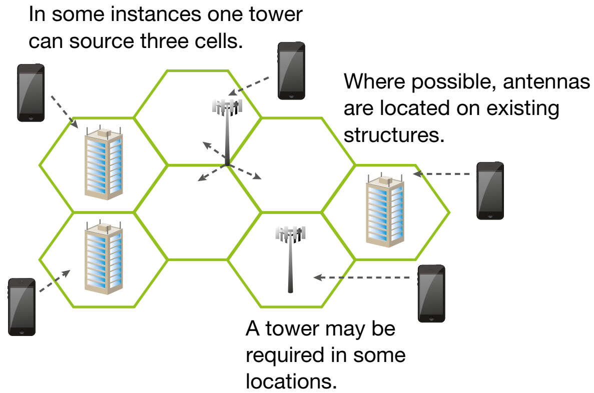
Going mobile

Since the first major mobile phone service was introduced in Australia in 1987, millions of Australians have purchased mobile phones.

How mobile phones work

Domestic and business telephones are connected by cable to the network of microwave and radio links, coaxial cables and optical fibres. Mobile phones transmit signals on radio waves to a **base station**, which consists of several antennas at the top of a large tower or on top of a tall building. The base station is connected to a **switching centre**. Each switching centre is, in turn, connected to many base stations. The switching centre switches the call to other mobile phones through the **cellular system** or the fixed telephone system.

The mobile phone network consists of a series of hexagonal cells that are serviced by base stations.



A network of cells

Mobile phones are also called **cell phones**. That is because the base stations are set up in a network of hexagonal cells.

Base stations may consist of large free-standing towers or structures located on building rooftops, and are located either in the centre of each cell or on the corner of a group of cells.

The cells range in size from 100 metres across to over 30 kilometres across depending on the terrain and the concentration of mobile phone users. The base stations receive and transmit mobile phone signals from the cells that adjoin them. In addition, each base station is connected to the main telephone network either via a high frequency radio wave antenna, or via optical fibre cable.

When you make a call, your mobile phone will always 'talk' to the base station antennas nearest to you. As you move around, the phone will 'talk' to different base stations, which ever is the closest, or the least congested.

Typical mobile phone base stations

The pathway followed by a mobile phone call

INVESTIGATION 4.21

The impacts of digital technology

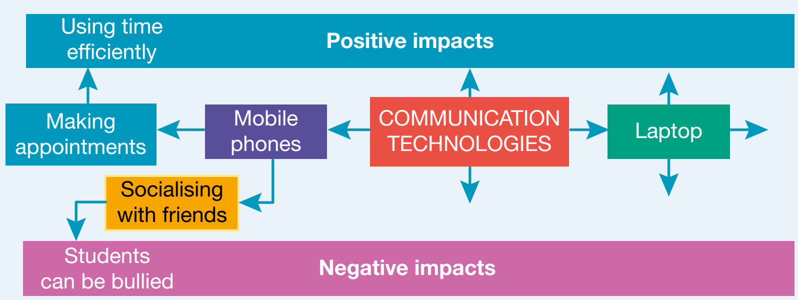
AIM: To evaluate the impact of new and emerging technologies on society and the environment

There is no doubt that fast and flexible digital technology is revolutionising the way we communicate at work and in recreation. In this investigation you will evaluate the impact of new and emerging digital technologies on society and the environment.

You will need:

butcher's paper

- Work in small groups and record the group's ideas in the form of a mind map.
- Identify digital technologies in common use. These may include a tablet, laptop, mobile phone, landline, MP3 player etc.
- For each technology, brainstorm the specific uses for that device in your work or recreation.
- For each use, brainstorm any positive or negative impacts on society (physical health, mental health, lifestyle, productivity, etc.) or the environment (pollution, waste etc.).



Discussion

1. Using information in your mind map, individually, discuss, using examples, the positive and negative impacts of digital communication technologies on society and the environment.
2. Give reasons why society should support scientific research in the development of better communication technologies.

4.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note*: Question numbers may vary slightly.

Remember

1. **Summarise** the differences between the digital and analogue signals that are added to carrier waves for television transmission.
2. Digital television has several advantages over analogue television.
   (a) List three of these advantages.
   (b) **Explain** why digital signals have these advantages.
3. **Identify** the components of a coaxial phone cable that:
   (a) carries the analogue or digital signal
   (b) reduces interference.
4. **Explain** why repeater stations are necessary for the transmission of microwaves and other radio waves.
5. Use a labelled diagram to **describe** total internal reflection.
6. **Explain** when total internal reflection can occur.
7. **Explain** how light can be used to transmit the signals from phones or computers.
8. **Describe** how mobile phones are different from landline telephones in the way that they transmit and receive voice messages.
9. **Explain** why mobile phones are also known as cell phones.

Think

10. **Explain** why repeater stations are necessary along coaxial cables.
11. **Explain** why microwaves and other radio waves are preferred for communication in the outback rather than optical fibres or coaxial cables.
12. **Explain** why communication satellites are placed in geostationary orbit.
13. **Identify** an analogue device (or technique) that measures:
    (a) time
    (b) speed
    (c) weight
    (d) pH.
14. **Construct** a table to list the advantages and disadvantages of mobile phones over landline phones.
15. Refraction is the bending of light as it passes from one medium to another. **Describe** the role of refraction in an optic fibre.

Investigate

16. Research using secondary sources the progress on the optic fibre roll out. When will your suburb be provided with optic fibre to the home?
17. Photonics is the study of optic fibres and their application. Research how scientists in Australia are developing a computer chip based on light pulses rather than electrical circuitry.
18. Some people are concerned that the electromagnetic radiation from mobile phones and base stations could affect people's health. Research this area and **assess** the arguments put forward.

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Complete this digital doc: Worksheet 4.6: Communications (doc-12758)

4.6 Project: Did you hear that?

4.6.1 Did you hear that?

Scenario

Since the invention of the Walkman — a portable cassette tape player — in 1979, through to the modern iPod, we have loved to carry our favourite music around with us everywhere we go. Wherever you look, you'll see people walking the dog, riding the bus, going for a run, hitting the books or just sitting around hooked in to an audio device of some form. With more than 220 million iPods alone sold since their release in 2001 and the increasing affordability of personal music players in general, more and more people are spending time plugged in. But for every person who loves their MP3 player, there's another who'll be warning them that channelling all that sound directly into their ears will have long-term effects on their hearing.

Your fifty-year-old principal wonders whether there aren't short-term effects as well, because she finds it difficult to hear her mobile ringing for about ten minutes after she has stopped listening to music on her iPod. She comes to your science class (known for their cleverness) for some possible answers. One clever classmate suggests that maybe the type of music she was listening to had lots of high frequency sounds in it and that this had somehow affected her ear's ability to pick up the high frequencies of her mobile ring tone. Another clever classmate thinks that maybe she had the volume up too high on her iPod and that this might have caused some temporary deafness. A cheeky classmate suggests that maybe she can't hear it because she's old! Somewhat grumpy with that last comment, your principal decides that maybe she should just ban all personal music players in the school unless you can provide her with some thorough scientific evidence that something other than age can have short-term effects on hearing range after iPod use.

Your task

Using personal music players and online hearing tests, your group will perform a series of scientific investigations to explore the short-term effects of personal music players (such as iPods) on hearing range. You will then present your findings in the form of a scientific report suitable for sending to the principal.

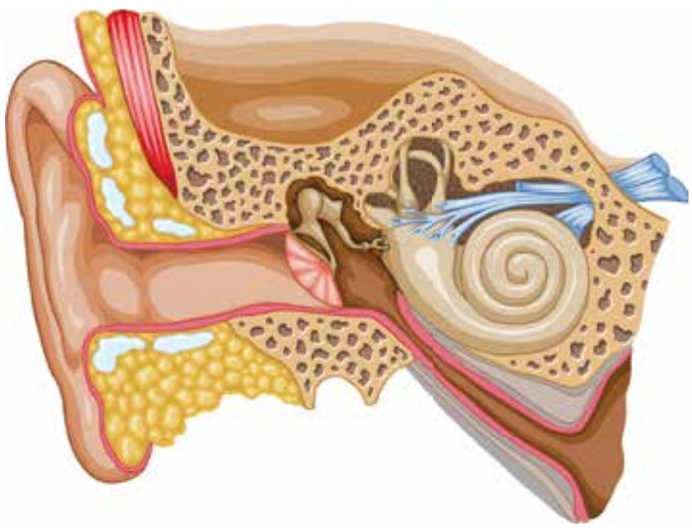
Suggested factors to consider include:

- volume used
- hearing range differences between males and females
- type of music (for example, classical, jazz, R&B or pop).

Note that you will need to minimise any risk of permanently causing damage to the hearing of your human subjects by ensuring that the volume does not exceed 90 dB and limiting trial durations to a few minutes.

Process

- You can complete this project individually or invite other members of your class to form a group.
- Start researching. Make notes of information that you gather that will provide background for your investigation and direct its design. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about human hearing and the factors that might influence a person's hearing range.
- Design your investigation by determining what will be the dependent, independent and controlled variables, establishing the use of controls and repeated measurements, and deciding what factors you will test and how you will measure the hearing range of your subjects.
- Perform your investigation. Take photographs during your investigation for inclusion in your report.



4.7 Review

4.7.1 Waves — carriers of energy

- **explain**, using the particle model the processes underlying convection and conduction of heat energy 4.2
- **identify**, with the use of examples the transfer of energy by waves 4.2
- **compare** longitudinal (compression) waves and transverse waves 4.2
- **describe**, using the wave model, the features of waves including frequency, wavelength and speed 4.2
- **explain**, using the particle model, the transmission of sound in different media 4.2

4.7.2 Light

- **identify** visible light as a form of electromagnetic radiation 4.3
- **identify** the properties of electromagnetic waves 4.3
- **describe** the reflection of light from plane and curved mirrors and identify some useful applications 4.3
- **describe** and **account for** the refraction of light and outline everyday instances in which refraction is evident 4.3
- **describe** the way in which lenses focus light and identify some useful applications of lenses 4.3

4.7.3 Colour vision

- **describe** how the eye functions to provide vision 4.4
- **account for** the colour of objects in terms of absorption, transmission and reflection of the colour spectrum 4.4
- **describe** some familiar examples of scattering and dispersion 4.4

4.7.4 The communication revolution (SHE)

- **identify** the features of different types of radiation in the electromagnetic spectrum and their uses 4.5
- **compare** AM and FM radio 4.5
- **compare** analogue and digital signals and **outline** the advantages of digital technology 4.5
- **describe** advances in technology involved in our communication network, in particular the coaxial cable, wireless and optic fibre technology 4.5
- **describe** the scientific principles involved in optic fibre communication 4.5
- **describe** the scientific principles and the technology involved in communication using landline phones and mobile phones 4.5

Individual pathways

ACTIVITY 4.1
Investigating invisible waves
doc-10643

ACTIVITY 4.2
Analysing invisible waves
doc-10644

ACTIVITY 4.3
Investigating invisible waves further
doc-10645

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FOCUS ACTIVITY

Create a poster or multimedia presentation that explains clearly to your peers how we perceive different colours and how the eye works to provide vision in colour.
Access more details about focus activities for this topic in the Resources tab (doc-10642).

4.7 Review 1: Looking back

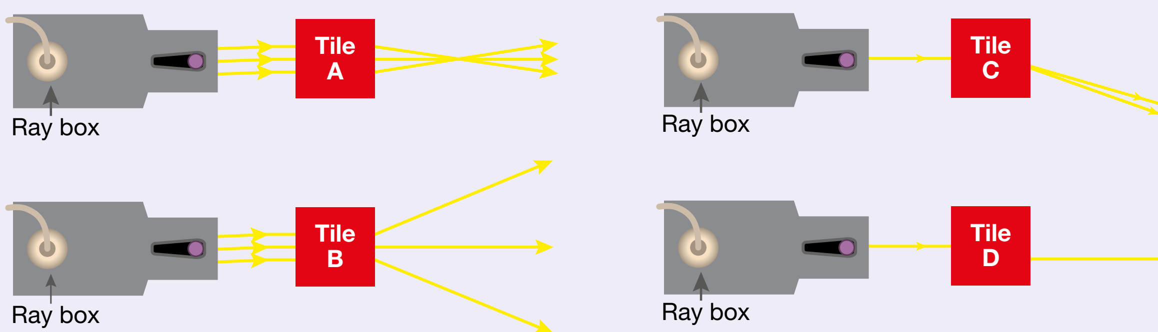
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. When heating water in a metal pot, **identify** how most of the heat is transferred through:
   (a) the metal base of the pot
   (b) the water in the pot.
2. The waveform at right was produced by plucking a string on an electric guitar. Copy the waveform. In another circle of the same size, draw a waveform that:
   (a) shows a louder sound
   (b) has a higher pitch.

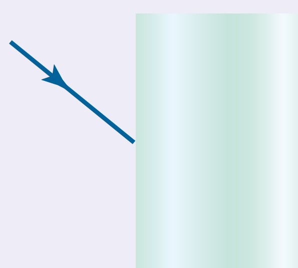
3. Copy and complete the table below, indicating with a tick which statements refer to light and which refer to sound. Some of the statements apply to both light and sound.

Statement	Light	Sound
Travels through empty space at 300 000 km/s		
Can be reflected		
Always caused by vibrating objects or substances		
Can travel through transparent substances		
Cannot travel through opaque objects		
Can be measured in decibels		
Can be produced from another form of energy		
Is detected by receptors in the human body		

4. (a) **Explain** why sound waves cannot travel through empty space.
   (b) **Explain** why light waves can travel through empty space.
5. Thin beams of light are projected from a ray box towards four objects. Each object is covered by a tile. The beams emerging from each of the objects are shown in the diagrams below.
   Identify the object under each tile.

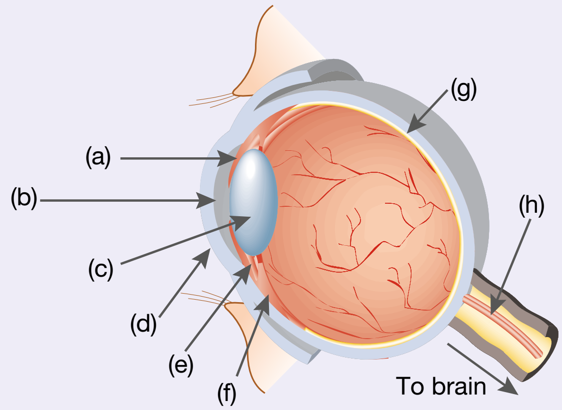


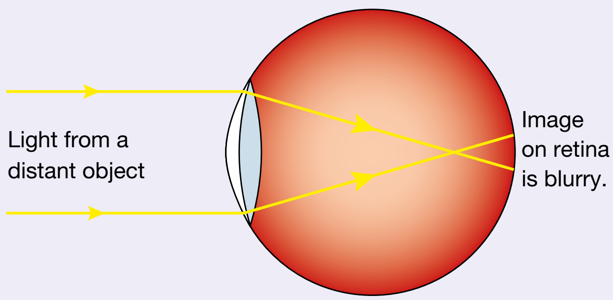
6. Copy and complete the diagram at right to show the path of the light ray as it passes through a glass rectangular prism and emerges into the air on the other side.



7. A light ray passes from air to glass and back into air again. **Identify** how its speed changes when it enters the glass. As a result, does the light ray refract towards or away from the normal?
8. Use a diagram to **explain** why your legs appear to be shorter when you stand in clear, shallow water.
9. **Identify** whether a convex lens has a greater focal length if it is thick or thin. Draw a diagram to illustrate your answer.

10. **Identify** the parts of the eye labelled (a)–(h) and **outline** the main function of each of the parts labelled. **Construct** a table to record this information.
11. The diagram below right shows how rays from a distant object arrive at the retina of a person with blurry distance vision.
    (a) **Identify** the condition illustrated below right.
    (b) **Outline** what the correcting lens needs to do to the incoming light to correct the problem.
    (c) Draw a diagram to show how an appropriate lens placed in front of the eye shown can correct this eye condition.
12. Imagine that you are riding on parallel beams of light as they enter a human eye. Write an account of your journey on the beam from the time that you reach the eye until you arrive at the receptor cells in the retina.
13. **Explain** how the eye can focus on both near and distant objects.
14. **Explain** how you are able to see so many different colours when receptor cells on the surface of your retina are able to detect only red, green and blue light.
15. **Describe** what happens to white light when it passes through a blue filter.
16. **Explain** why:
    (a) blue paint appears blue when it is illuminated by white light
    (b) a white shirt can look red when you are at a dance or concert
    (c) a green shirt can look black when you are at a dance or concert.
17. Make a copy of the table at right. However, rearrange the invisible waves in the first column so that they are listed in order of increasing frequency. Complete the table by filling in the other column.
18. **Identify** three differences between sound waves and the waves listed in the table at right.
19. **Identify** two properties that all of the waves listed in the table have in common.
20. **Identify** which type of electromagnetic waves listed in the table microwaves belong to.
21. **Identify** which of the electromagnetic waves listed in the table at right:
    (a) transmits the most energy
    (b) is used in remote control devices.
22. **Describe** how digital radio signals are different from analogue radio signals.
23. List some reasons why analogue television was phased out and replaced with digital television.





Electromagnetic waves

Electromagnetic wave type	Uses
Infra-red radiation	
Gamma rays	
Ultraviolet radiation	
Light	
X-rays	
Radio	

Test yourself

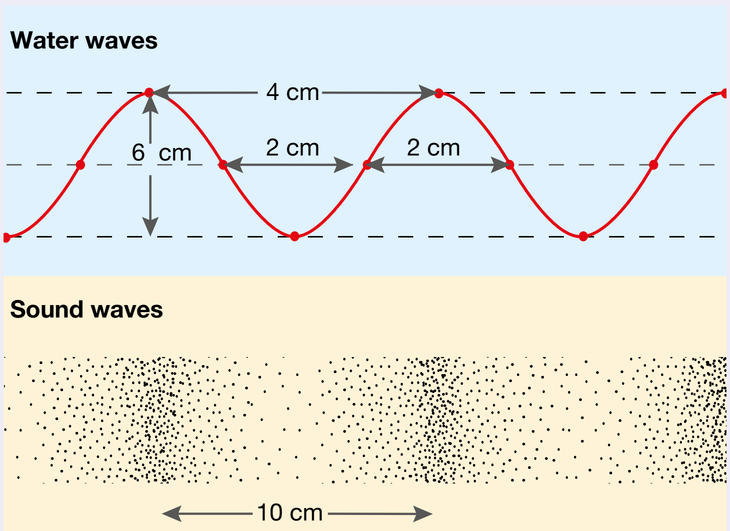
1. A feature of sound waves is that they
   (A) travel at about 340 m/s through air.
   (B) do not require a medium to travel through.
   (C) consist of troughs and crests.
   (D) travel faster through less dense objects like liquids than through solids. **(1 mark)**
2. **Identify** the structure(s) of the eye responsible for refracting light.
   (A) The lens
   (B) The pupil
   (C) The cornea and lens
   (D) The retina **(1 mark)**

3. A make-up mirror would consist of a
   (A) plane mirror.
   (B) convex mirror.
   (C) convex lens.
   (D) concave mirror. **(1 mark)**
4. Which of the following options correctly matches an electromagnetic wave with its common application?

	Electromagnetic wave	Application
A	Microwaves	Killing cancerous cells
B	Radio waves	Mobile phone communication
C	Infra-red radiation	Cooking
D	Gamma rays	Remote controls

(1 mark)

5. A blue light passes through a red filter. Light coming through the filter will be
   (A) blue.
   (B) red.
   (C) white.
   (D) black, there will be no light. **(1 mark)**
6. The questions below refer to the water wave and sound wave shown in the following figure. **(2 marks)**



   (a) **Identify** the amplitude and the wavelength of the water wave.
   (b) **Identify** the wavelength of the sound wave.
7. **Explain** how visible light is used to transmit phone calls along optical fibres. Use diagrams to illustrate your explanation. **(3 marks)**

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Complete this digital doc: Worksheet 4.7: Invisible waves puzzles (doc-12759)

Complete this digital doc: Worksheet 4.8: Invisible waves summary (doc-12760)

TOPIC 5 Chemistry — the inside story

5.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

5.1.1 Why learn this?

The air that you breathe, the gunpowder in fireworks and the boiling hot spray discharged by a bombardier beetle are all examples of chemicals. In fact everything around you, including your own body, is entirely composed of chemicals. Chemistry is the study of substances and the way that they behave on their own or when combined with other substances. To understand the behaviour of substances, you need to take a look inside to find out what they are made of.

The characteristics of a chemical, including its colour, state of matter and reactivity, are determined by the types of atoms that make up the chemical and the type of bonding between the atoms.

LEARNING SEQUENCE

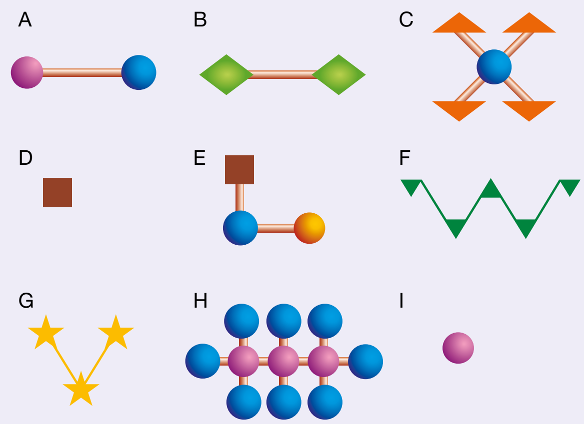
Do you have the inside information?

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

All chemicals — in other words all substances — are made up of tiny particles. These tiny particles are so small that you can't see them, even with the most powerful light microscope. You probably already know quite a lot about the particles inside chemicals. This knowledge is the first step in your quest to find out why chemicals behave the way they do.

Answer the questions below to find out how much you already know about the inside story on chemicals.

1. The substances around you and inside you can be placed into three groups — elements, compounds and mixtures.
   (a) Which one of these groups contains chemicals that are made up of only one type of atom?
   (b) Which one of these groups is the least likely to be found naturally in the Earth's crust?
   (c) What is the difference between a compound and a mixture?
   (d) Arrange the substances listed at the bottom of the page into the three groups of substances to complete the table below right.
2. Elements, compounds and mixtures are made up of tiny particles called atoms and molecules.
   (a) How is a molecule different from an atom?
   (b) List two elements that can be made up of molecules.
   (c) List two compounds that are made up of molecules.
   (d) Name one compound that is not made up of molecules.
3. Which of the diagrams at right represent:
   (a) an atom of an element?
   (b) a molecule of an element?
   (c) a molecule of a compound?
4. Identify the chemical element or elements that match each of the following descriptions.
   (a) They combine chemically to produce water.
   (b) It is neither a metal nor a non-metal and is used in electric circuits inside electronic devices such as computers and mobile phones.
   (c) It has the symbol Na.
   (d) They combine chemically to produce the compound that we know as pure salt.
   (e) It is the only metal that exists as a liquid at normal room temperatures.



gold
blood
carbon dioxide
diamond
iron
sea water
air
copper
chocolate thick shake
table salt
soil
ammonia
concentrated hydrochloric acid
pure water
calcium
brass
sodium hydroxide
oxygen

SUBSTANCES

Elements	Compounds	Mixtures

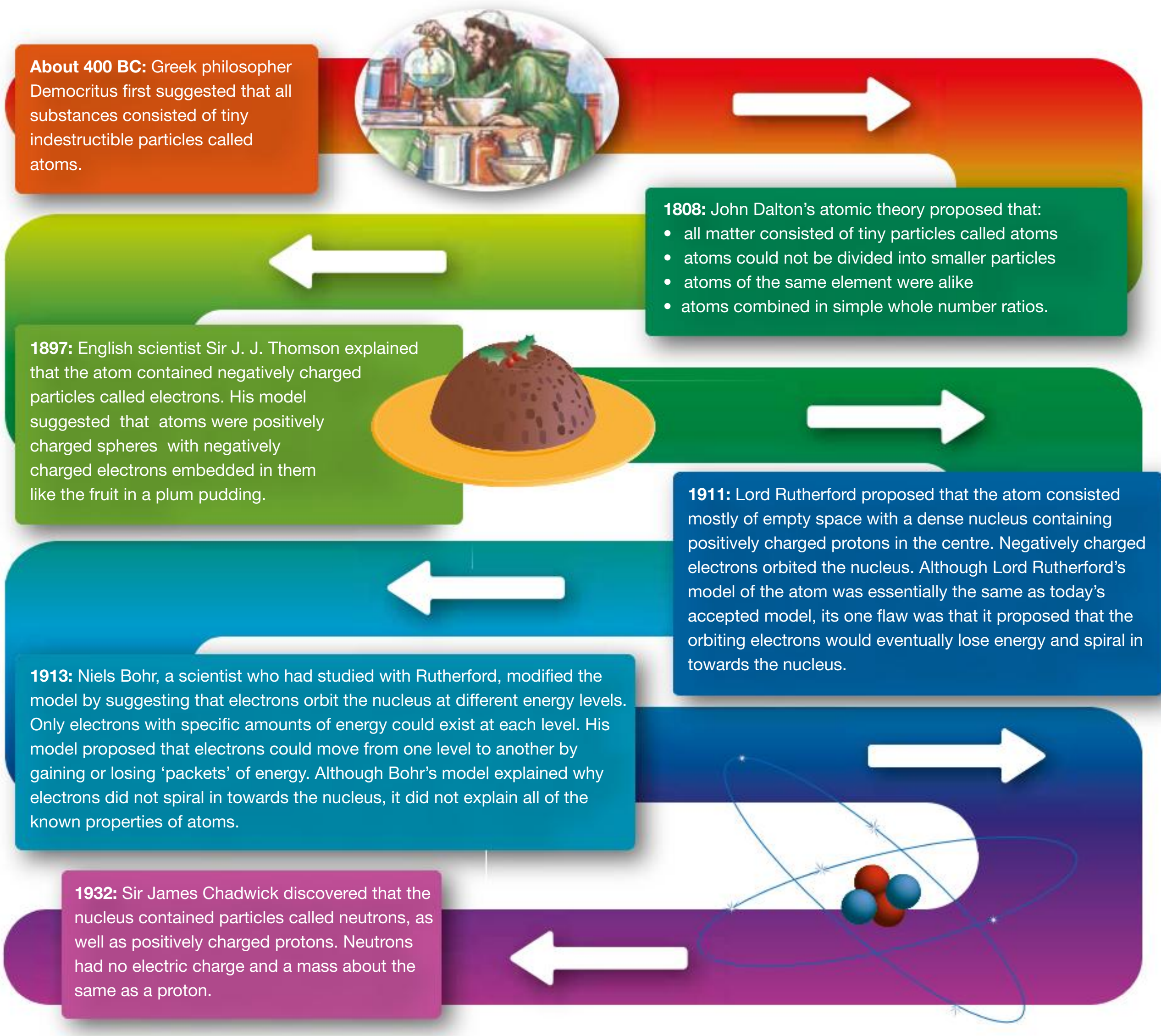
5.2 Chemical building blocks

Science as a human endeavour

5.2.1 A history of ideas about the atom

All matter in the universe is made up of tiny particles of different kinds. While atoms are not the smallest of these particles, they are the smallest particles that exhibit specific chemical properties. What these properties are depends upon the type of atom that you are looking at. By now you have probably learned that there are 92 individual types of naturally occurring atoms on Earth. What you may not know is that it has taken thousands of years for us to gain our present understanding of what an atom is, what makes them different from each other and how these differences contribute to their various chemical and physical properties.

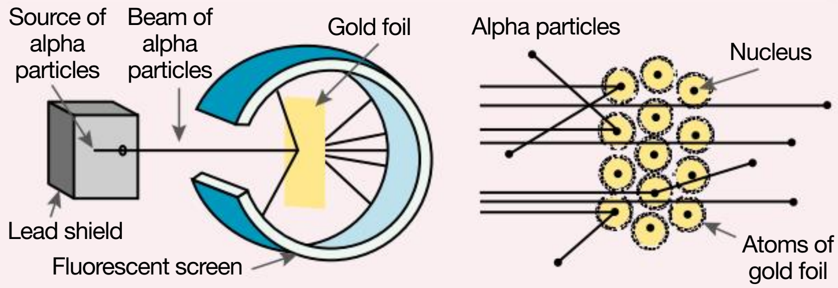
Most of our knowledge about the 'building blocks' of matter is less than 100 years old. We now know those 'building blocks' as atoms. The idea that matter was made up of atoms was first suggested about 2500 years ago by a Greek philosopher named Democritus. Since then, various theories and models of the atom have been accepted, rejected and modified. The flowchart below shows how our knowledge about the atom developed.



HOW ABOUT THAT!

Lord Rutherford's model of the atom was based on experiments in which he fired tiny positive alpha particles at very thin sheets of gold foil. Most of the particles went straight through the gold foil and very few were reflected back. He explained that the few particles that were reflected back were repelled by a very small, positively charged nucleus in the atoms of the gold. Most of the alpha particles, he said, continued through the foil because each gold atom consists mainly of empty space. Lord Rutherford said later that his observations were about as credible as if you had fired a 16-inch shell at a piece of tissue paper and it had come back and hit you!

An enlarged view of the gold foil experiment



Ernest Rutherford determined that the majority of the mass in an atom was located in the centre and that most of an atom's volume is empty space by firing positively charged particles at gold atoms in a thin foil and then looking at the paths the fired particles took. In investigation 5.1 you can model this process by firing ball bearings at a hidden nucleus and using the way the marbles bounce back to determine where the hidden nucleus is.

INVESTIGATION 5.1

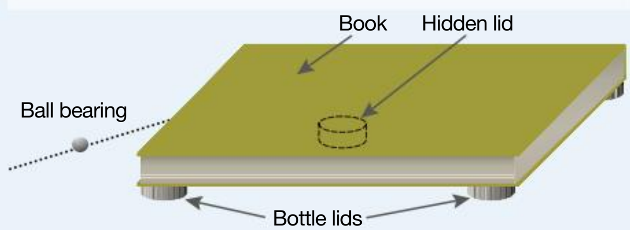
Find the nucleus!

AIM: To model Rutherford's nuclear model of the atom

You will need:

a hardcover textbook at least A4 in size
5 lids from soft-drink bottles
a 10 mm diameter ball bearing

A model of Rutherford's experiment



- Suspend the textbook above the bench top by placing a lid under each corner.
- While the rest of the group turns their backs, one member will lift the textbook and place the fifth lid somewhere within the area bounded by the four lids. They will then replace the textbook. This fifth lid represents the nucleus of the atom.
- Once the other students have turned around, they are to take turns rolling the ball bearing under the textbook to pinpoint the location of the nucleus, taking note of how many times the ball bearing is rolled before the nucleus is struck for the first time.
- When the shooters have come to a final decision as to where the nucleus is located, the student who did the hiding must lift the textbook to reveal whether the shooters were correct.
- Repeat with different students in the group taking turns to hide the nucleus. In each case, remember to note how many times the ball bearing was rolled before the nucleus was first struck.

Discussion

1. Determine the average number of times your group had to roll the ball bearing before striking the nucleus.
2. Imagine that one of the nucleus hiders decided to put the nucleus/bottle cap in their pocket rather than under the textbook. How many times do you think you would have had to roll the ball bearing to discover that there was no nucleus there?

5.2.2 The current model

At the moment, the accepted model of an atom is that it consists of a small, dense **nucleus** made up of **neutrons** (uncharged particles) and **protons** (positively charged particles) that is surrounded by rapidly moving, negatively charged **electrons**. While the neutrons and protons are roughly the same size, an electron is about 1/2000th the size of a proton.

The neutrons and protons of a nucleus are tightly bound together by very strong **nuclear forces**. The protons are all positively charged and, as you'll probably recall from your earlier studies, objects that have the same charge tend to repel each other. If it weren't for the strong nuclear forces, the protons would push each other away and the nucleus (and the atom) would disintegrate!

On the other hand, there is an attractive force between the negatively charged electrons and the positively charged protons. It is this force which keeps the electrons moving around the nucleus.

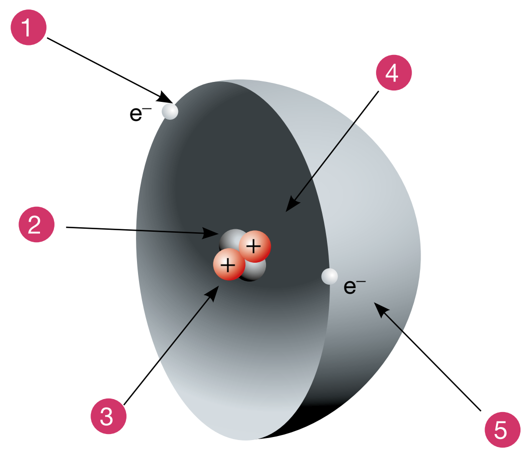
The distance between the electrons and the nucleus is huge. If the nucleus of the simplest atom (hydrogen) were the size of an orange, its electron would be about 10 kilometres away! As a result, most of the volume of an atom is made up of empty space. Yet when we look at very high resolution scans from powerful electron microscopes, the atoms look more like little solid balls. How can that be if they are mostly empty space?

Think of whirling a yoyo on its string in a circle. If you swing it around at a low speed, it is quite easy to see the yoyo. If you swing it very fast, however, the moving yoyo seems to turn into a blurry circle rather than an individual object. This is kind of what happens with the electrons except, because they move very fast all around the nucleus, the moving electrons form a sort of fuzzy sphere or shell around the nucleus. This is sometimes referred to as the **electron cloud**.

The number of protons in an atom determines what type of atom it is. For example, every atom with 79 protons is a gold atom, and every gold atom has 79 protons. Substances that are made up of only one type of atom are called **elements**.

Electrons move rapidly around the nucleus. Although they follow no set paths, electrons are always found in regions called **electron shells**.

1. Electrons are about 1/2000th the size of protons and neutrons. Electrons have an electrical charge of negative one (–1). An atom has the same number of electrons as protons. The charges balance out so an atom has no electrical charge. It is said to be neutral.
2. A neutron has no electrical charge.
3. Protons and neutrons make up the nucleus. They are held together by very strong nuclear forces. Almost all of the mass of an atom is in the nucleus.
4. Protons and neutrons are almost the same size. A proton has an electrical charge of positive one (+1). The number of protons in an atom determines what type of atom it is. For example, every atom with seventynine protons is a gold atom, and every gold atom has seventy-nine protons. Substances that are made up of only one type of atom are called **elements**.
5. Electrons move rapidly around the nucleus. Although they follow no set paths, electrons are always found in regions called **electron shells**.



5.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Using the present model, name the three parts of an atom. **Explain**
   (a) what electric charges they carry and
   (b) where they may be found in the atom.

2. **Describe** the 'plum pudding' model of the atom.
3. In what ways were the atomic models of Democritus and Dalton (a) similar (b) different?
4. What was the main problem with Rutherford's 'planetary' model of the atom?
5. Which scientist first named (a) electrons (b) protons (c) neutrons?
6. **Explain** why the model of the atom has changed over time.
7. **Explain** how protons are different from neutrons. How are they similar?
8. **Describe** the differences between protons and electrons.
9. **Recall** where most of an atom's mass is located.
10. What holds the protons and neutrons together in the nucleus of an atom?

Think

11. Why do you think that the neutron was the last of the atom components to be discovered?
12. Why has no-one been able to directly observe the nucleus of an atom up to now?
13. Is the current model of the atom a theory or a fact? **Explain** your answer.
14. Was John Dalton's statement, that atoms are indivisible, correct? **Explain**.

Create

15. Use the information on these pages to make 3D versions of the different atomic models that have been formulated over the centuries.

Investigate

16. **Investigate** one of the following scientists and describe their contributions to our knowledge about the structure of the atom. In your report you need to include: (a) full name, place of birth, date of birth and death; (b) a brief description of the type of work the scientist did in his/her lifetime; (c) their contribution to our understanding of the structure of the atom; (d) the technology available to the scientist that enabled him/her to make the discovery; (e) description of how relevant the scientist's theory is to today's understanding of the structure of the atom. Choose from: John Dalton, Sir William Ramsay, Marie Curie, J. J. Thomson, Henry Moseley, Max Planck, Eugen Goldstein, Lord Rutherford, Frederick Soddy, Sir James Chadwick, Niels Bohr, Louis de Broglie, Lise Meitner.
17. Today we know of many particles smaller than neutrons and protons. Find out more about some of these particles and how they are investigated.

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Complete this digital doc: Worksheet 5.1: The structure of the atom (doc-12761)

5.3 All charged up!

5.3.1 Electron shells

All neutral atoms have the same number of electrons as they do protons — in other words, the same number of negative charges as positive charges. In the simplest atom, the hydrogen atom, there is one proton and one electron.

One of the largest atoms, uranium, has 92 protons and 92 electrons. This means that there are an awful lot of electrons flying around the nuclei of many atoms, yet they don't run into each other. In fact, the electrons move between layers of spherical shells so that there are only a few electrons in the same vicinity.

Each electron shell has room for only a certain number of electrons, and the further out from the nucleus an electron shell is, the more electrons it can hold. A general rule is that the maximum number of electrons that a shell can hold is equal to $2n^2$ where n is the shell number.

This means that the first shell ($n = 1$) can hold $2 \times 1^2 = 2$ electrons at most while the second shell ($n = 2$) can hold a maximum of $2 \times 2^2 = 8$ electrons. The third shell can take a maximum number of $2 \times 3^2 = 18$ electrons and so on up to the seventh shell.

These outermost shells are filled only in the largest atoms.

It is often useful to represent the structure of an atom with an **electron shell diagram**. In these diagrams the nucleus of the atom, containing protons and neutrons, is drawn in the middle. Electron shells are drawn as a series of concentric rings around a nucleus.

The shells closest to the nucleus contain electrons that have the lowest energy. As you go through the shells away from the nucleus, the electrons have increasing amounts of energy. While things get a bit more complicated in the third shell (as we shall see later in the topic), electrons moving around a nucleus are generally arranged so that the lowest shells fill first. Let's see how this works.

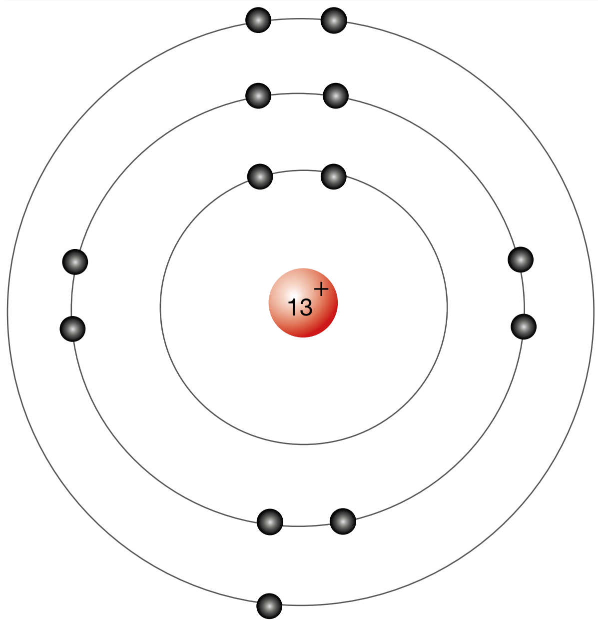
The nucleus of an aluminium atom is surrounded by shells of electrons in the following diagram. Aluminium has 13 protons in its nucleus, so it must have 13 electrons distributed among its shells. Filling the shells from the lowest levels, we can see that the first shell will be filled with two electrons, and the second shell will be filled with eight electrons. This accounts for 10 of our 13 electrons. The last three electrons will be located in the third shell from the nucleus.

You will note from the diagram that the electrons are shown in pairs. This reflects an aspect of atomic structure that you will cover in more depth in your senior science studies.

The electron arrangement of an atom can be written by showing the number of electrons in each shell from the innermost shell, with commas in between. For example, the electron arrangements of aluminium, sodium and oxygen can be written as:

Aluminium	2, 8, 3
Sodium	2, 8, 1
Oxygen	2, 6.

Aluminium has 13 protons and, therefore, 13 electrons. The electrons fill the first two shells completely. Three electrons are in the outermost shell.

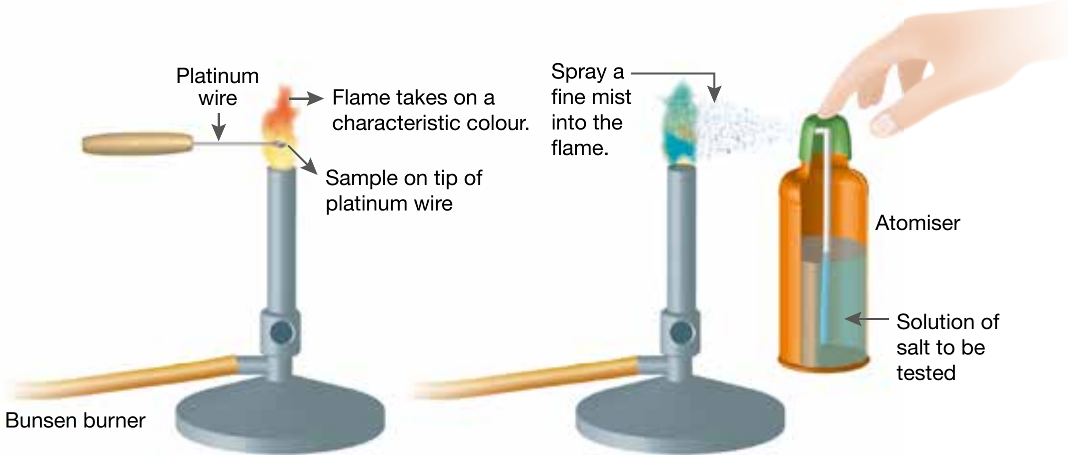


5.3.2 Upwardly mobile electrons

The electron arrangement of an atom may be changed as a result of energy being added to the atom; for example, energy being added in the form of heat from a flame. This extra energy can cause electrons to move further away from the nucleus into orbits with bigger radii. When this occurs the atom is said to be in an **excited state**. This movement is temporary, however, and eventually the electrons drop back to their original shell locations — this is called the atom's **ground state**. When they drop back down, they release that extra energy in the form of light. The colour of this light indicates the amount of energy that the electron has released. The electrons in a particular atom tend to release the same quantities of energy each time, so the different atoms have characteristic light colours associated with them.

A flame test allows the metal present in a salt compound to be identified from the colour a Bunsen flame turns when the compound enters the Bunsen flame. For example, a compound that turns the flame green will most likely contain copper. The diagram on the next page shows two ways of doing a flame test, while a third method is used in Investigation 5.2.

Various metal ions produce characteristic colours when they are volatilised in a flame.



INVESTIGATION 5.2

Flame tests

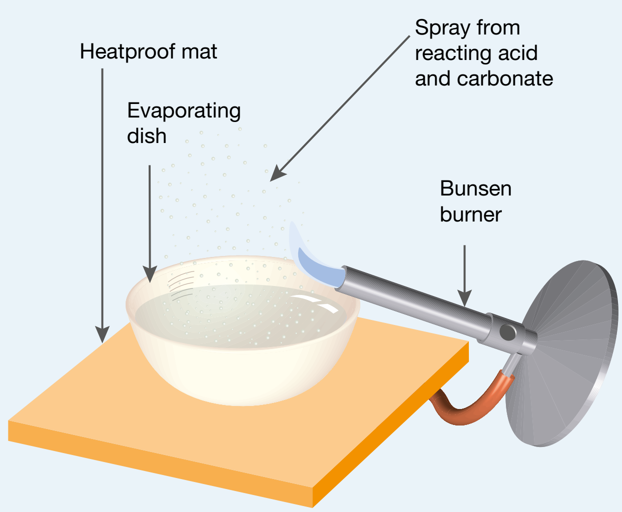
AIM: To observe the visible light radiation that is released when electrons return to their ground state after being raised to an excited state by the energy from a Bunsen flame

You will need:

safety glasses and laboratory coat
2 M hydrochloric acid
Bunsen burner, heatproof mat and matches
5 evaporating dishes
barium carbonate
sodium carbonate
copper carbonate
potassium carbonate
strontium carbonate
10 mL measuring cylinder
spatula

CAUTION: Laboratory coats and safety glasses must be worn at all times.

- Place 10 mL of 2 M hydrochloric acid in an evaporating dish and place the dish on the heatproof mat.
- Add a spatula full of the barium carbonate to the evaporating dish.
- Carefully hold the lit Bunsen burner at an angle over the spray produced by the reacting acid and carbonate as shown in the diagram at right. Observe the change in the colour of the flame.
- Repeat using the other carbonates. Use a different evaporating dish each time.



Discussion

1. Record the colours produced by the different carbonates in a suitable table.
2. Flame tests provide evidence that electrons do actually occupy different shells. Why do elements produce different colours?
3. Is it the metal part of the compound or the carbonate part (carbon and oxygen) that produces the colour? How do you know?

5.3.3 Ions

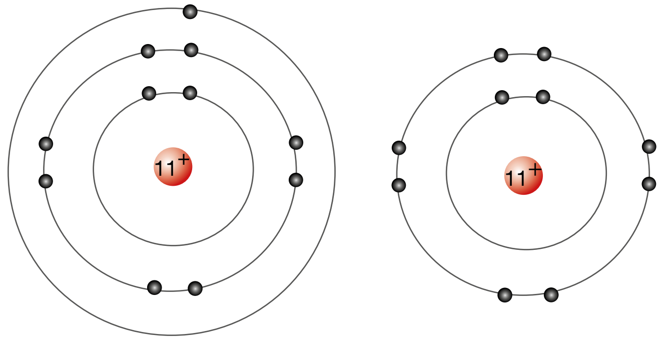
An **ion** is an atom that has gained or lost one or more electrons. **Positive ions** are atoms that have lost electrons. They have more protons than electrons, so they carry a positive electrical charge. **Negative ions** are atoms that have gained electrons. They have more electrons than protons, so they carry a negative electrical charge.

When the outer shell is full, an atom is more stable. Atoms 'lose' or 'gain' electrons so that their outer shells become 'filled' if they are not already full.

In the case of the sodium atom in the diagram at right, there is one electron in the outer shell — the shell is not full. The sodium atom loses one electron to become more stable. The chlorine atom has seven electrons in its outer shell, but needs eight to have a full shell. So, the chlorine atom gains an electron and forms a negatively charged chloride ion.

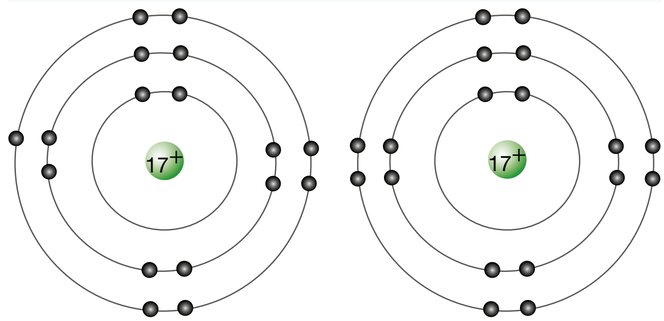
Atoms gain or lose electrons depending on which is the easier way to have a full outer shell. It is easier for sodium to lose that electron than to fill its outer shell. But it is easier for chlorine to gain one electron, rather than lose seven.

Sodium atoms lose electrons to become positive sodium ions.



Sodium atom (Na) Sodium ion (Na^+)

Chlorine atoms gain electrons to become negative chloride ions.



Chlorine atom (Cl) Chloride ion (Cl^-)

5.3.4 Naming ions

Positive ions keep the name of the atom from which they are made. So, a positive ion made from a copper atom is called a *copper ion* and the positive ion formed from boron is called a *boron ion*.

Negative ions, on the other hand, have names that are slightly different from those of the atoms from which they are derived. For example, the negative ion formed by fluorine is called a *fluoride ion* while the negative ion that nitrogen forms is called the *nitride ion*.

In general, the name of a negative ion is found by using the first part of the atom's name and then adding 'ide' to the end of it.

5.3.5 Writing symbols for ions

We can show whether an ion is positive or negative by using the chemical symbol for the atom that the ion is derived from and adding the appropriate sign as a superscript. We can also show in the superscript how many electrons the atom has gained or lost to become an ion. For example, calcium tends to form a positive ion by losing 2 of its electrons, so the calcium ion is written as Ca^{2+}. Chlorine gains a single electron to form a negative ion which is written as Cl^{1-} or just Cl^-.

The following table shows the names and symbols of some common ions.

Positive ions			Negative ions		
Atom name	**Ion name**	**Chemical symbol**	**Atom name**	**Ion name**	**Chemical symbol**
lithium	lithium	Li^+	iodine	iodide	I^-
sodium	sodium	Na^+	fluorine	fluoride	F^-

Positive ions			Negative ions		
Atom name	**Ion name**	**Chemical symbol**	**Atom name**	**Ion name**	**Chemical symbol**
potassium	potassium	K^+	chlorine	chloride	Cl^-
calcium	calcium	Ca^{2+}	oxygen	oxide	O^{2-}
aluminium	aluminium	Al^{3+}	nitrogen	nitride	N^{3-}

HOW ABOUT THAT!

People who are lucky enough to have seen an aurora — either the Aurora Borealis in the north or the Aurora Australis in the south — describe it as looking like massive coloured curtains of light that shift like they are being blown by the wind, and in a way they are! This amazing light show is caused by the solar wind — a stream of high energy ions produced by the sun — interacting with the gas atoms in our atmosphere within the Earth's magnetic field, which is strongest at the poles. These interactions cause energy in the form of light to be produced, forming the aurora in the layer of the atmosphere called the ionosphere.

The lights of the Aurora Borealis (seen here in Landmannarlaugar, Iceland) are produced by the ions from the solar wind interacting with our atmosphere in the Earth's magnetic field.

5.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What is the name given to the different energy levels that electrons can be found in?
2. How many electrons are needed to fill (a) the first shell (b) the second shell?
3. How is an ion different from an atom?
4. **Explain** how an oxide ion is formed.
5. State whether the following atoms form positive or negative ions: (a) oxygen; (b) boron; (c) chlorine; (d) lithium.
6. The ion formed from a zinc atom has the symbol Zn^{2+}. (a) Does the zinc atom lose electrons or gain electrons to form this ion? (b) How many electrons does it gain or lose to form the ion?

Think

7. Look at the diagram of the sodium atom and sodium ion. (a) How many electrons does the atom have? (b) How many electrons does the ion have? (c) **Explain** why the sodium ion carries a positive charge.
8. How many electrons are there in: (a) a neutral carbon atom with 6 protons? (b) a neutral neon atom with 10 protons?
9. Copy and complete the following table using the information above as well as the periodic table in subtopic 5.4. The first entry has been done for you.

Ion symbol	Ion name	Gained electron or lost electrons?	Number of electrons lost/gained	Total number of electrons in ion
F^-	fluoride	gained	1	10
Be^{2+}				
N^{3-}				
Cl^-				
Sn^{2+}				
Ag^+				

Investigate

10. The ionosphere is an important part of Earth's atmosphere. Find out where in the atmosphere it is, who first discovered it, what it is made from and why it is so important to life on Earth.
11. The different colours in the auroras are the result of ions interacting with the gases in the Earth's atmosphere. Find out what gases cause red, blue and green light to be produced in an aurora.

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Complete this digital doc: Worksheet 5.2: Electron shells (doc-12762)

5.4 Searching for patterns

5.4.1 The periodic table of elements

Russian chemist Dmitri Mendeleev confidently predicted the properties of the chemical element germanium 15 years before it was discovered. He was able to do this because all known elements had been arranged into a set of rows and columns called the **periodic table**.

Two thousand years ago, only 10 elements had been identified. They were carbon, sulfur, iron, copper, zinc, silver, tin, gold, mercury and lead. By the early nineteenth century, over 50 elements had been identified. Chemists had already begun to search for patterns among the elements in the hope of finding a way to classify them. It was difficult at that time to find patterns because there were still many undiscovered elements.

In 1864, British chemist John Newlands arranged the elements in order of increasing atomic weight and found that every eighth element shared similar properties. In 1869, Mendeleev, building on the work of Newlands and other scientists, discovered a way of organising the elements into rows and columns. This arrangement formed the basis of what we now know as the periodic table. The elements were arranged in rows in order of increasing mass or atomic weight. Mendeleev called the rows of elements periods and the columns, which each contained a 'family' of elements, groups. It is called the periodic table because elements with similar properties occur at regular intervals or periods. In a strange twist of fate, German chemist Lothar Meyer, who worked independently of Mendeleev, also came up with a similar arrangement of the elements at about the same time.

The observation that the physical and chemical properties of the elements recur at regular intervals when elements are listed in order of atomic weight is known as the **Periodic Law**.

5.4.2 An educated guess

Mendeleev was so confident about the Periodic Law that he deliberately left gaps in his periodic table. He was able to predict the properties of the unknown elements that would fill the gaps. Mendeleev predicted the existence of germanium, which he called eka-silicon. This element was discovered in 1886, 15 years later. The table below shows the uncanny accuracy of Mendeleev's predictions.

Properties of eka-silicon as predicted by Mendeleev	Properties of germanium which was discovered in 1886
A grey metal	A grey-white metal
Melting point of about 800 °C	Melting point of 958 °C
Relative atomic mass of 73.4	Relative atomic mass of 72.6
Density of 5.5 g/cm^3	Density of 5.47 g/cm^3
Reacts with chlorine to form compounds with four chlorine atoms bonded to each eka-silicon atom	Reacts with chlorine and forms compounds in a ratio of four chlorine atoms to every germanium atom

Mendeleev's work led many scientists to search for new elements. By 1925, scientists had identified all of the naturally existing elements.

The periodic table includes the names, symbols and atomic numbers of all the known elements. The symbols are a form of shorthand for writing the names of the elements and are recognised worldwide. Some periodic tables describe the properties of each element, including its physical state at room temperature, melting point, boiling point and relative atomic mass. Most elements exist as solids under normal conditions and a few exist as gases. Only two elements exist as liquids at normal room temperature.

5.4.3 Counting sub-atomic particles

The periodic table is organised on the basis of atomic numbers. The **atomic number** of an element is the number of protons present in each atom. Atoms with the same atomic number have identical chemical properties. Because atoms are electrically neutral, the number of protons in an atom is the same as the number of electrons. The **mass number** of an atom is the sum of the number of protons and neutrons in the atom. The number of neutrons in an atom can therefore be calculated by subtracting the atomic number from the mass number. This information is usually shown in the following way: ${}^{A}_{Z}E$

A = the mass number
= number of protons + number of neutrons
Z = the atomic number
= number of protons
= number of electrons (for a neutral atom)
E = the symbol of the element.

For example, the element iron has a mass number of 56 and an atomic number of 26. It can be represented as follows:

$${}^{56}_{26}\mathrm{Fe}$$

Once you know the atomic number and the mass number of an element, you can work out how many electrons and neutrons are in that element.

The atomic number of iron is 26 because all iron atoms have 26 protons. Iron's mass number of 56 indicates that most iron atoms have a total of 56 protons and neutrons.

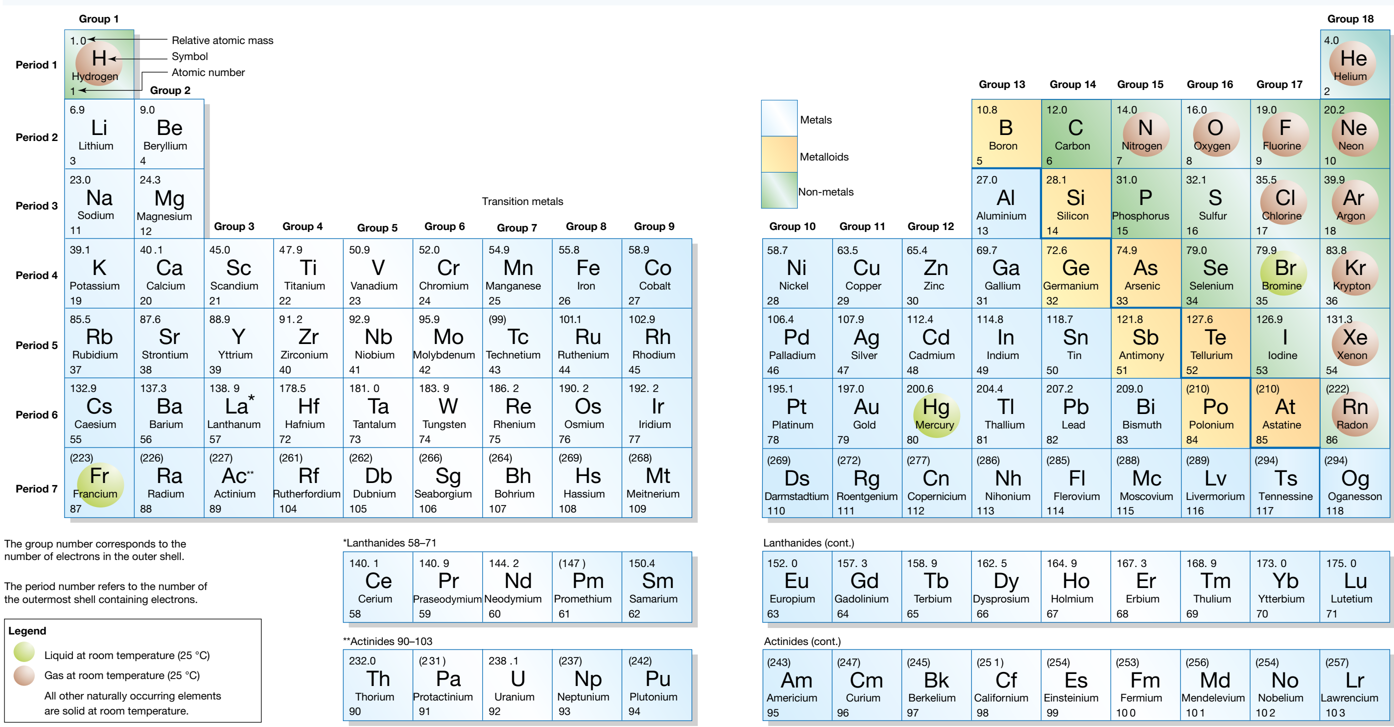
To calculate the number of neutrons, the atomic number is subtracted from the mass number to give 30 neutrons:

$$\textbf{number of neutrons} = A - Z = 56 - 26 = 30$$

Since atoms are electrically neutral and protons have a positive charge, each iron atom has 26 electrons:

$$\textbf{number of electrons} = \textbf{number of protons} = Z = 26$$

The periodic table.



5.4.4 How heavy are atoms?

Measuring and comparing the masses of atoms is difficult because of their extremely small size. Chemists solve this problem by comparing equal numbers of atoms, rather than trying to measure the mass of a single atom.

A further problem arises because not all atoms of an element are identical. Although all atoms of a particular element have the same atomic number, they can have different numbers of neutrons. Hence, some elements contain atoms with different masses. These different masses are used to calculate an average or **weighted mean**, which is based on the relative amounts of each type of atom. This number is referred to as the **relative atomic mass** and is usually not a whole number.

For example, 99.98% of all hydrogen atoms have 1 proton only in their nucleus and so have an atomic mass of 1. However, about 0.015% of hydrogen atoms have a proton and one neutron in their nucleus (giving them an atomic mass of 2) and the remaining hydrogen atoms found have one proton and two neutrons in their nuclei, giving them an atomic mass of 3. As a result, the relative atomic mass of hydrogen is 1.008 rather than 1.

Rounding off the relative atomic mass to the nearest whole number will usually give you the mass number (A) of the most common form of an element.

5.4.5 Families of elements

The periodic table contains eighteen groups (or families) of elements, some of which have been given special names. (Remember that these groups form columns in the periodic table.)

- Group 1 elements are known as the **alkali metals**. The alkali metals all react strongly with water to form basic solutions.
- Group 2 elements are referred to as the **alkaline earth metals**.
- Group 17 elements are known as the **halogens**.
- Group 18 elements are known as the **noble gases**. The noble gases are inert and do not readily react with other substances.
- The block of elements in groups 3 to 12 is known as the **transition metal** block.

Illuminated signs use tubes filled with the noble gas neon.

5.4 Exercise: Remember and think

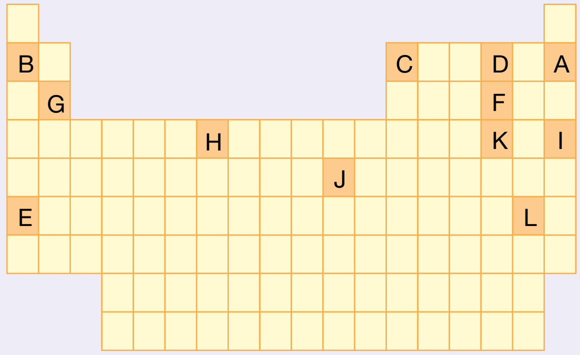
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. State whether the following statements are true or false.
   (a) The noble gases are found in group 18.
   (b) The non-metals are found in the upper right-hand side of the periodic table.
   (c) There are more metals than non-metals.
   (d) Few elements are found naturally as liquids.
2. **Identify** the element in: (a) group 2, period 3 (b) group 17, period 2 (c) group 1, period 4 (d) group 18, period 3.
3. **Construct** an outline of the periodic table showing where you would find the following elements: the noble gases, the alkali metals, the alkaline earth metals, the halogens and the transition metals.
4. In the outline of the periodic table shown on the next page, some of the elements have been replaced by letters. Using these letters, **identify** which of these elements fit the following categories.
   (a) Two elements that are gases at room temperature
   (b) Two elements that are metals
   (c) Two elements that are transition elements

(d) An element that is a noble gas
(e) Two elements that are in the same group
(f) Two elements that are in the same period
(g) The elements that are alkali metals
(h) The element that is a halogen

5. **Distinguish** between the mass number and the relative atomic mass of an element.
6. **Construct** a table showing the name, mass number, atomic number, and number of protons, neutrons and electrons of the following elements.
   (a) $^{12}_{6}C$
   (b) $^{65}_{30}Zn$
   (c) $^{40}_{18}Ar$
   (d) $^{197}_{79}Au$
   (e) $^{238}_{92}U$



Think

7. **Explain** why it is useful to display the elements as a periodic table rather than as a list.

Investigate

8. Scientists have created all the elements beyond element 92. **Investigate** how they have been made.

Create

9. Compose a rhyme, poem or song that can help you learn the names of the first 20 elements in order.

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Try out this interactivity: Periodic table (int-0758)

Complete this digital doc: Worksheet 5.3: Elements and atomic numbers (doc-12763)

Complete this digital doc: Worksheet 5.4: Periodic table (doc-12764)

5.5 Periodic patterns

5.5.1 Is it a metal?

The line that zigzags through the periodic table separates the **metals** from the **non-metals**. About three-quarters of all elements are classified as metals. The metals are found on the left-hand side of the table. The non-metals are found on the upper right-hand side of the table. Eight elements that fall along this line have properties belonging to both metals and non-metals. They are called **metalloids**. Examples of these elements include silicon, boron and germanium.

5.5.2 Following a trend

There are a number of repeating patterns in the periodic table. The most obvious is the change from metals on the left of each period to non-metals on the right. Other patterns exist in the physical and chemical properties of elements in the same group or period. Some of these trends are shown in the table on the next page.

Characteristic	Pattern down a group	Pattern across a period
Atomic number and mass number	Increases	Increases
Atomic radius	Increases	Decreases
Melting points	Decreases for groups 1 to 5 and increases for groups 5 to 8	Generally increases then decreases
Reactivity	Metals become more reactive and non-metals become less reactive	Is high, then decreases and then increases. Group 8 elements are inert and do not react.
Metallic character	Increases	Decreases

INVESTIGATION 5.3

Chemical properties of metals and non-metals (Teacher demonstration)

AIM: To investigate and compare some reactions of metals and non-metals

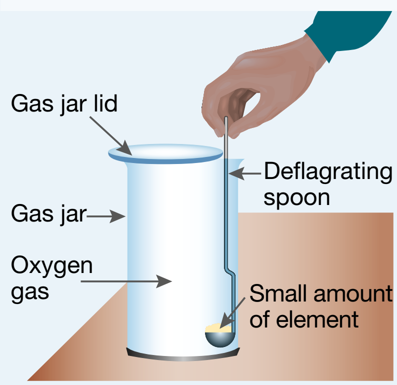
You will need:

safety glasses, gloves and laboratory coat
1 M hydrochloric acid
water
magnesium
iron filings
copper filings
sulfur powder
universal indicator
4 test tubes
4 gas jars filled with oxygen gas
4 deflagrating spoons
dropping pipette
spatula
Bunsen burner, heatproof mat and matches

CAUTION: This experiment should be done in a fume cupboard. Safety glasses, gloves and laboratory coats must be worn at all times.

- Place a small quantity of magnesium in a test tube. Add about 2 mL of hydrochloric acid. Record any observations in a suitable table.
- Repeat using the iron filings, copper filings and sulfur powder.
- Place a small amount of magnesium in a deflagrating spoon and heat it. When hot, place it into the gas jar full of oxygen gas. **Do not look directly at the flame.** Record your observations.
- Repeat using the iron and copper filings. Record your observations.
- Repeat using a small amount of sulfur powder.
- Add about 10 mL of water to each jar and shake. Add 3 drops of universal indicator. Record the colour and determine the pH of the solution.

Burning sulfur in oxygen in a gas jar



Discussion

1. Use the periodic table to determine which of the elements tested were metals and which were non-metals.
2. Describe any differences between the effect of acids on metals and non-metals.
3. Describe what happened when the metals and non-metals reacted with oxygen.
4. The metal or non-metal oxides formed in the gas jars dissolved in water to form acidic and basic solutions. What type of solution did the metals form? What type of solution did the non-metals form?

5.5.3 Explaining the periodic table

When Mendeleev and Meyer grouped elements on the basis of their similar chemical properties, they were not aware of the existence of electrons. We can now explain many of their observations using our understanding of electron shells.

Atoms in the same group of the periodic table have similar properties because they have the same number of electrons in their outer shells. (The outer shell is the last shell to be filled by electrons.) The number of electrons in the outer shell relates to the group number in the periodic table. Hence, all elements in group 1 have one electron in their outer shell and all elements in group 18 (with the exception of helium) have eight electrons in their outer shell.

INVESTIGATION 5.4

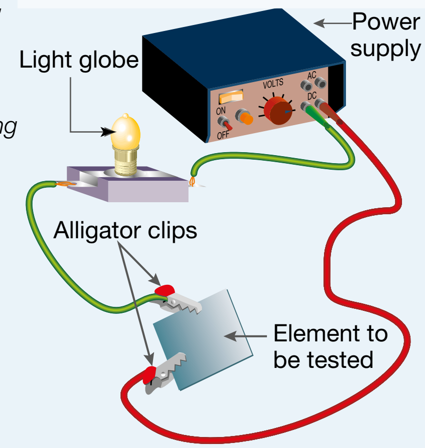
Comparing the properties of two metal families

AIM: To investigate and compare metal elements from group 2 (the alkaline earth metals) and the transition metals

You will need:

small samples of magnesium, iron and copper
'rice grain' equivalent amounts of calcium chloride, magnesium chloride, iron chloride and copper chloride
spatula
5 test tubes and a test-tube rack
electric circuit to measure conductivity (2-volt power supply, 3 connecting leads, 2 alligator clips and a light globe and holder)
2 M hydrochloric acid
water
matches
stirring rod
safety glasses and laboratory coat

Circuit used to measure electrical conductivity



- Record the results of the following experiments in an appropriate table.
- Describe the physical state (solid, liquid or gas) of each of the elements.
- Describe the physical appearance of each of the elements.
- Set up the circuit as shown in the diagram above right and determine whether each of the elements conducts electricity.
- Determine whether any of the elements react with water by placing a small sample in 2 mL of water in a test tube. Record any changes that occur in your table.
- Determine whether the metals react with acid by placing a small sample of each metal in 1 mL of 2 M hydrochloric acid in a test tube. If a gas is produced, test it by holding a lit match at the mouth of the test tube. Make sure the test tube is pointed away from you. If hydrogen is present, a 'pop' will be heard. If oxygen is present, the match should burn more brightly. If carbon dioxide is present, the match should go out.
- Your teacher may show or describe to you how the metal calcium responds to some of the tests described previously.
- Add a small amount of each of the metal compounds (magnesium chloride, calcium chloride, iron chloride and copper chloride) to 5 mL of water. Comment on their solubility and the colour of any solution made.

Discussion

1. What are the properties of copper and iron? Are there any similarities?
2. What are the properties of calcium and magnesium? Are there any similarities?
3. List the metals in order of reactivity with water and acids. List them in order of most reactive to least reactive.
4. Were there any differences between solubilities of the metal compounds or the colours of the solutions they formed? Describe these differences.
5. Write down the name of the specific group in the periodic table to which each of the elements belong.
6. What could you infer about the properties of elements in the same group? Give reasons for your answer.

5.5.4 Shell by shell

The largest atoms contain up to seven shells of electrons. Thus, there are seven periods (rows) in the periodic table. (Look at the periodic table to confirm this.) The period number tells you the number of shells containing electrons. The first shell can hold up to two electrons, so there are two elements in the first period (with hydrogen containing one electron in the first shell and helium containing two electrons in the first shell). The second shell holds up to eight electrons, so there are eight elements in the second period.

Even though the third shell can hold up to 18 electrons, there are only eight elements in the third period. This is because the outer shell of an atom can never hold more than eight electrons as the atom would then become unstable. Therefore, while the third shell is yet to be filled, electrons begin to fill the fourth shell in both potassium and calcium atoms. This stabilises the atoms because the third shell is no longer the outer shell. The filling of the third shell resumes in the block of elements from scandium to zinc (the transition metals). Once the third shell is full, the fourth shell continues to fill from gallium to xenon.

Element	Symbol	Atomic number	Electronic configuration
Oxygen	O	8	2, 6
Fluorine	F	9	2, 7
Neon	Ne	10	2, 8
Sodium	Na	11	2, 8, 1
Magnesium	Mg	12	2, 8, 2
Sulfur	S	16	2, 8, 6
Chlorine	Cl	17	2, 8, 7
Argon	Ar	18	2, 8, 8
Potassium	K	19	2, 8, 8, 1

Note that the fourth shell of the potassium atom begins filling before the third shell is full.

HOW ABOUT THAT!

Lead poisoning was a common occurrence in ancient Rome because the lead the Romans used to make their water pipes and cooking utensils slowly dissolved into the water.

Acute lead poisoning causes mental impairment and personality changes. The effects of lead poisoning are not immediately noticeable. They occur gradually as the amount of lead in the body accumulates over time. Some historians attribute the strange behaviour of several Roman emperors to lead poisoning.

In the Middle Ages plates, cups and other drinking vessels were often made from pewter, an alloy of lead and tin. The acids in food and drinks caused lead to leach out and cause poisoning.

Until 1986, lead was added to petrol to stop the 'knocking' in car engines. Unleaded fuel was introduced at that time to allow a device called a catalytic converter to prevent pollutants such as nitrous oxides, carbon monoxide and unburnt fuel from being emitted from car exhausts. With lead in the petrol, these devices couldn't work. It was also believed that lead emissions from cars were causing a build-up of lead in the humans in built-up areas.

The word 'plumber' is derived from the Latin word *plumbum*, meaning lead. Look up the symbol for lead in the periodic table. Where do you think this symbol came from?

5.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember

1. **Describe** what happens to the metallic character of the elements as you go across the periodic table.
2. What information about the electron arrangement is given by the group number of an element?
3. What information about the electron arrangement is given by the period number of an element?

Think

4. **Explain** why water does not appear in the periodic table.
5. Name the elements that have an electron arrangement of: (a) 2,4 (b) 2,8,5 (c) 2 (d) 2,8,8,2.
6. Write the electron arrangement for each of the following elements.
   (a) Boron
   (b) Neon
   (c) Potassium
   (d) Fluorine
   (e) Silicon
7. If an element has one electron in its outer shell, is it a metal or a non-metal? **Explain** your answer.
8. If an element has seven electrons in its outer shell, is it a metal or a non-metal? **Explain** your answer.
9. What is special about elements that have eight electrons in their outer shell?
10. What experimental evidence is there to show that electron shells actually exist?

Investigate

11. It is said that the stars are the 'element factories of the universe'; that is, stars make the elements. Do some research and investigate how the stars make elements.
12. Choose an element and research the following information about it: (a) when it was discovered (b) who discovered it (c) how it is found in nature (d) its properties and uses.
13. The electron arrangement of elements is more complex than the explanation given here. Find out about subshells and orbitals and how they are involved in determining how electrons are arranged in atoms.

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Try out this interactivity: It's elementary (int-0229)

5.6 Ionic compounds

5.6.1 Molecules and compounds

Atoms are not often found on their own. When the outer shell electrons of atoms interact, atoms can become chemically joined together to form molecules. The join is called a **chemical bond** (or **molecular bond**). Bonds can form between atoms of the same element or between atoms of differing elements. You should recall from your earlier Science studies that a substance that is made from atoms of differing elements bonded to each other is called a **compound**.

Knowledge of the electron shell structures of atoms helps us to understand how compounds like sodium chloride (table salt) form. When atoms react with each other to form compounds, it is the electrons in the outer shell that are important in determining the type of reaction which occurs.

5.6.2 It's great to be noble

In 1919, Irving Langmuir suggested that the noble gases do not react to form compounds because they have a stable electronic configuration of eight electrons in their outer shell. Most other atoms react because their electron arrangements are less stable than those of the noble gases. The atoms become more stable when they attain an electron arrangement that is the same as the noble gases. Chemical reactions can allow atoms to obtain this arrangement. The table on the next page shows the electron arrangement of a few elements. Notice how the electron arrangements of the two noble gases, neon and argon, show eight electrons in their outer shells. The atoms of the other elements must gain or lose electrons to attain full outer shells. In this way they become more stable, ending up with the electron arrangement of the nearest noble gas in the periodic table.

Element	Electron arrangement
O	2, 6
F	2, 7
Ne	**2, 8**
Na	2, 8, 1
Mg	2, 8, 2
S	2, 8, 6
Cl	2, 8, 7
Ar	**2, 8, 8**
K	2, 8, 8, 1

5.6.3 Giving and taking electrons

Atoms that have lost or gained electrons and therefore carry an electric charge are called ions. Metal atoms, such as sodium, magnesium and potassium, have a small number of outer shell electrons. They form ions by losing the few electrons that they have in their outer shell. This means that metal ions have more protons than electrons and so the ions are positively charged. For example, the magnesium atom loses its two outer shell electrons to become a positively charged magnesium ion. The symbol for the magnesium ion is Mg^{2+}. The '2+' means that two electrons have been lost to form the ion. Positively charged ions are called **cations**.

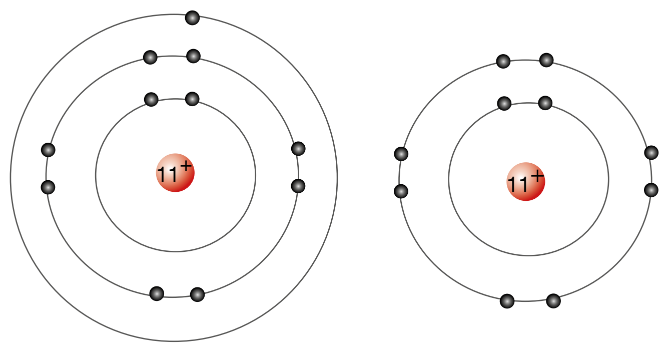
Non-metal atoms form ions by gaining electrons to fill their outer shell. In these ions there are more electrons than protons, so they are negatively charged. For example, the chlorine atom gains one electron to fill its outer shell, becoming a negatively charged chloride ion. Its symbol is Cl^{-}. The '–' means that one electron has been gained to form the ion. Negatively charged ions are called **anions**.

The diagram at right shows how sodium and chlorine atoms lose and gain electrons respectively to form ions. Note that the sodium atom becomes a sodium ion and that the chlorine atom becomes a chloride ion. (Remember, when non-metals form ions, the suffix '-ide' is used.)

Compounds such as sodium chloride, copper sulfate, calcium carbonate and sodium hydrogen carbonate all form when atoms come in contact with each other and lose or gain electrons. Compounds formed in this way are called **ionic compounds**.

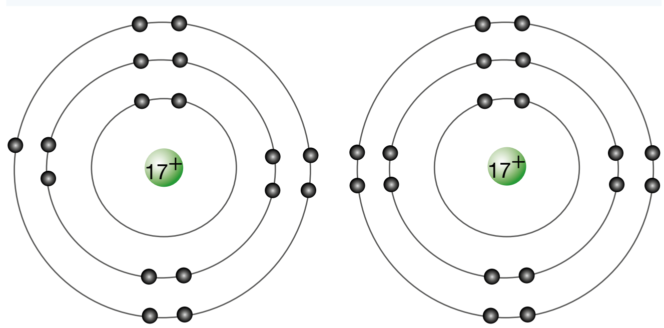
Ionic compounds form when metal and non-metal atoms combine. A sodium atom loses an electron to form an ion, and a chlorine atom gains an electron to form an ion. The electrons are transferred from one atom to the other, and the oppositely charged ions that form attract each other and form a compound. This electrical force of attraction between the ions is called an **ionic bond**.

Sodium atoms lose electrons to become positive sodium ions.



Sodium atom (Na) Sodium ion (Na^{+})

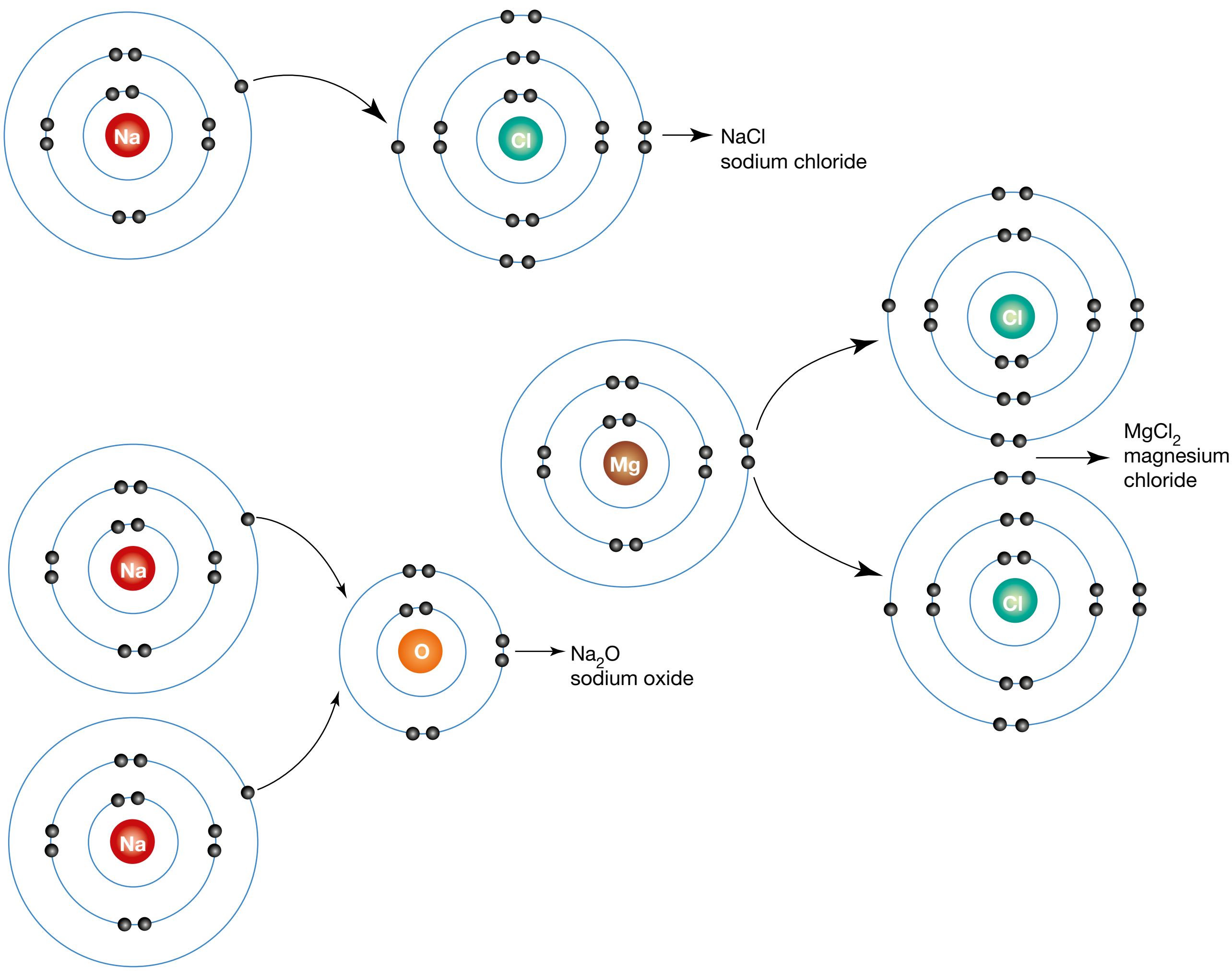
Chlorine atoms gain electrons to become negative chloride ions.



Chlorine atom (Cl) Chloride ion (Cl^{-})

The diagram below shows some examples of the transfer of electrons that occurs when ionic compounds are formed. Note that more than two atoms may be involved to ensure that all the elements achieve a full complement of electrons in their outer shell. For example, when magnesium reacts with chlorine to form magnesium chloride, each magnesium atom loses two electrons. Since each chlorine atom needs to gain only one electron, a magnesium atom gives one electron to each of two chlorine atoms. The resulting Mg^{2+} and Cl^{-} ions are attracted to each other to form the compound $MgCl_2$.

The 'give' and 'take' of electrons that occurs in the formation of the ionic compounds sodium chloride, magnesium chloride and sodium oxide



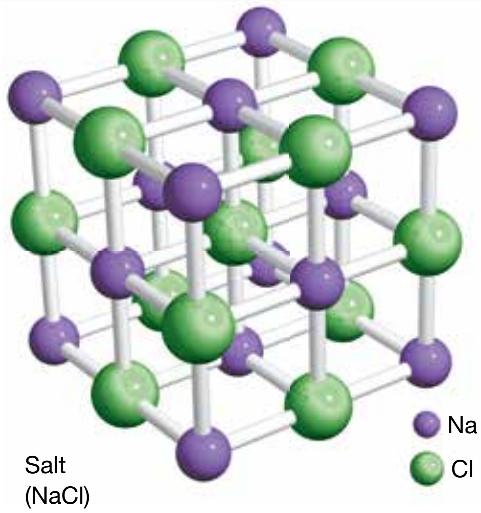
Characteristics of ionic compounds

Ionic compounds have the following properties.

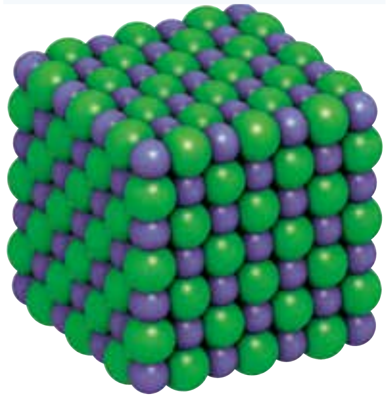
- They are made up of positive and negative ions.
- They are usually solids at room temperature.
- They normally have very high melting points because the electrostatic force of attraction between the ions is very strong.
- They usually dissolve in water to form **aqueous solutions**.
- Their aqueous solutions normally conduct electricity.

Ionic compounds usually form lattices of positive and negative ions rather than individual molecules. A lattice is an ordered structure of ions held together by the electrostatic attraction between the positive and negative ions and is the basis of crystal formation.

A ball and stick representation of the lattice structure of sodium chloride; the sticks represent the bonds between the atoms.



The ions in the lattice are effectively held in a tight arrangement.



Individual salt crystals form regular square blocks because of the ionic lattice.

5.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the term 'ion'.
2. **Describe** how ions form.
3. **Recall** what a positively charged ion is called.
4. **Recall** what a negatively charged ion is called.
5. **Recall** the properties that most ionic compounds have in common.
6. **Describe** the kinds of elements that combine to form ionic compounds.

Think

7. Why are you unlikely to find an isolated molecule of an ionic compound?
8. Write the symbol for the ion formed by each of the following elements. You can turn back to the periodic table: (a) sodium (b) nitrogen (c) potassium (d) fluorine.
9. **Identify** how many electrons have been gained or lost by the following ions: (a) Pb^{4+} (b) Br^{-} (c) Cr^{3+} (d) Se^{2-}
10. Which of the following are ionic compounds? Nitrogen dioxide; hydrogen chloride; magnesium sulfide; carbon tetrachloride
11. Draw diagrams to show how each of the following ionic compounds form. (a) Magnesium fluoride (b) Lithium chloride (c) Aluminium sulfide (d) Calcium oxide

Imagine

12. Imagine that you are the outer shell electron of a sodium atom and you are going to form the ionic compound sodium chloride. **Describe** your experiences in a piece of creative writing. **Discuss** details such as the physical states, properties of the elements and compound involved, their atomic structure, reasons for forming ions and, finally, the reasons why the ions form the ionic compound.

learnON RESOURCES — ONLINE ONLY

- **Try out this interactivity:** Shell-shocked? (int-0676)
- **Try out this interactivity:** Pass the salt (int-0675)
- **Complete this digital doc:** Worksheet 5.5: Ionic bonding (doc-12765)

5.7 Covalent compounds

5.7.1 Electron dots and dashes

Ionic compounds form as the result of non-metal atoms effectively 'stealing' electrons from metal atoms. Atoms can also achieve stable electronic configurations by sharing electrons with other atoms to gain a full outer shell. When two or more atoms share electrons, a molecule is formed. A chemical bond formed by the sharing of electrons is called a **covalent bond**. The compounds formed are called **covalent** or **molecular compounds**.

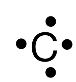
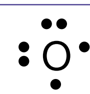
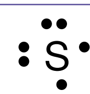
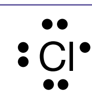
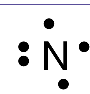
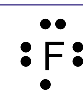
Non-metal atoms share electrons to form covalent molecules. These molecules can be made of more than one type of atom, or made of atoms of the same element. For example, oxygen gas consists of molecules formed when two oxygen atoms share electrons. Individual atoms of oxygen are not stable and become more stable by sharing electrons with each other.

It is possible to draw diagrams to show how elements share electrons to form covalent compounds. These diagrams are called **electron dot diagrams**. They show the symbol for the atom and dots for the electrons in the outer shell of atoms. The table below shows electron dot diagrams for some elements. Note that the electrons in the diagrams are arranged in four regions around the atom. Wherever possible, they are grouped in pairs.

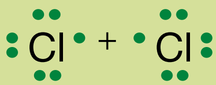
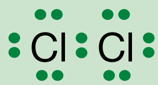
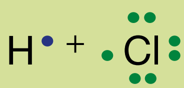
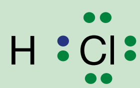
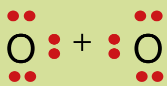
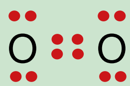
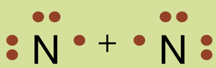
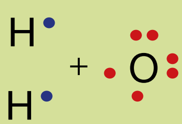
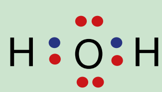
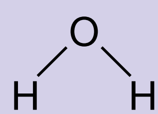
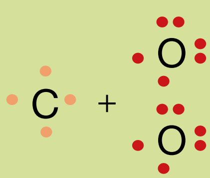
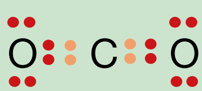
When elements combine to form covalent compounds, they share electrons in order to achieve a full outer shell with eight electrons. Hydrogen has a full outer shell when it has two electrons but all the other elements in the table need eight electrons to fill the outer shell.

The table on the next page shows how some covalent compounds form. The shared electrons are called **bonding electrons**. It is also possible to draw a **structural formula**, where a dash is used to represent these shared electrons. The dash represents the covalent bond and the other electrons need not be drawn. It is also possible for double or triple covalent bonds to form. The way electrons are shared determines the ratio in which elements combine to form a covalent compound. It also determines the **chemical formula** of the compound.

Electron dot diagrams for some elements

Symbol	Electronic configuration	Electron dot diagram
H	1	
C	2, 4	
O	2, 6	
S	2, 8, 6	
Cl	2, 8, 7	
N	2, 5	
F	2, 7	

The formation of covalent molecules

Name and formula	Atoms	Compound	Structural formula	Explanation
Chlorine Cl_2			Cl — Cl *Note:* The line represents a sharing of two electrons and is called a single covalent bond.	Each chlorine atom needs to share one electron to gain a full outer shell.
Hydrogen chloride HCl			H — Cl	Both the hydrogen and the chlorine atom need to share one electron to gain a full outer shell.
Oxygen O_2			O = O *Note:* The double line represents a double covalent bond.	Each oxygen atom needs to share two electrons to gain a full outer shell.
Nitrogen N_2			N ≡ N *Note:* The triple line represents a triple covalent bond.	Each nitrogen atom shares three electrons to gain a full outer shell.
Water H_2O				Each hydrogen atom needs one electron and the oxygen atom needs two electrons to gain a full outer shell.
Carbon dioxide CO_2			O = C = O	Each oxygen atom needs two electrons and the carbon atom needs four electrons to gain a full outer shell.

INVESTIGATION 5.5

Drawing electron dot diagrams

AIM: To practise drawing electron dot diagrams of covalent molecules

- Draw electron dot diagrams like those in the table on the previous page for the following covalent compounds: hydrogen fluoride (HF), methane (CH_4), phosphorus chloride (PCl_3) and hydrogen sulfide (H_2S).

Discussion

1. What pattern emerges between the structural formula of the compound and the number of electrons involved in bonding?
2. State whether the covalent bonds in the compounds are single, double or triple bonds.

5.7.2 Characteristics of covalent compounds

Most covalent compounds have the following properties.

- They exist as gases, liquids or solids with low melting points because the forces of attraction between the molecules are weak.
- They generally do not conduct electricity because they are not made up of ions.
- They are usually insoluble in water.

HOW ABOUT THAT!

The electron dot diagrams shown on page 212 are better known as Lewis structures, but they can also be called Lewis dot diagrams. These were developed by the American chemist Gilbert Newton Lewis, who discovered covalent bonds, as a way of notating the bonds between atoms joined together in covalent molecules. Lewis first used these diagrams in an article called 'The atom and the molecule' which was published in 1916. They are now commonly used by physical chemists.

5.7 Exercise: Remember and think

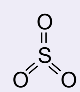
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

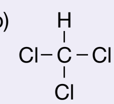
Remember

1. **Identify** what kinds of elements combine to form covalent compounds.
2. **Define** the term 'covalent bond'.
3. **Describe** what an element's electron dot diagram represents.
4. **Recall** what properties most covalent compounds have in common.

Think

5. **Distinguish** between a single covalent and a triple covalent bond, in terms of the number of electrons involved.
6. For the following covalent compounds, state whether their bonds are single, double or triple covalent.

(a)  sulfur trioxide – a gas which is used to make sulfuric acid

(b)  chloroform – a liquid which was once used as an anaesthetic

(c) H–C≡C–H acetylene – a colourless gas used in welding

7. (a) Draw electron dot diagrams to show how the following covalent compounds form: (i) Hydrogen fluoride (HF) (ii) Methane (CH_4) (iii) Phosphorus chloride (PCl_3) (iv) Hydrogen sulfide (H_2S) (v) Tetrachloromethane (CCl_4) (vi) Ammonia (NH_3) (vii) Carbon disulfide (CS_2)
   (b) What pattern emerges between the structural formula of the compound and the number of electrons involved in bonding?
   (c) State whether the covalent bonds in the compounds are single, double or triple bonds.
8. **Explain** why the noble gases don't form covalent compounds.
9. **Explain** why CO_2 (a compound) and O_2 (an element) are both molecules.

Investigate

10. Silicon dioxide, commonly known as silica or sand, is a hard solid covalent compound with a very high melting point. Find out about its structure.
11. Although carbon and graphite are both made up of carbon atoms, they have very different properties. **Investigate** their properties and explain why they are so different in terms of their covalent structure.
12. To find out more about atomic structure and bonding, use the **Atomic structures** weblink in the Resources tab.

learnon RESOURCES — ONLINE ONLY

Try out this interactivity: Making molecules (int-0228)

Explore more with this weblink: Atomic structures

Complete this digital doc: Worksheet 5.6: Covalent bonding (doc-12766)

5.8 Finding the right formula

5.8.1 It's elementary

Most of the chemicals used in your school science laboratory are identified by both a name and a formula. Most people are able to recognise the formula of common compounds like water (H_2O) and carbon dioxide (CO_2). A chemical formula (plural 'formulae') is a shorthand way of writing the name of an element or compound. It tells us the number and type of atoms that make up an element or compound. Writing the correct formula is of paramount importance in chemistry. Most chemical problems cannot be solved without the knowledge of chemical formulae.

Often the formula of a substance is simply the symbol for the element. Metals such as iron and copper, which contain only one type of atom, are identified simply by the symbol for that element (e.g. Fe and Cu). Noble gases such as neon (Ne) have a similar formula.

Some common non-metal molecules and their molecular formulae

Name	Formula
Hydrogen	H_2
Nitrogen	N_2
Chlorine	Cl_2
Bromine	Br_2
Oxygen	O_2
Sulfur	S_8
Phosphorus	P_4

Some non-metal elements such as hydrogen, oxygen and nitrogen exist as simple molecules. These molecules form when atoms of the same non-metal join together by covalent bonds. For example, the formula for the element hydrogen is H_2, indicating that two hydrogen atoms are joined together to make each molecule of hydrogen. A **molecular formula** is a way of describing the number and type of atoms that join to form a molecule.

5.8.2 Formulae of compounds

The formula of a compound shows the symbols of the elements that have combined to make the compound and the ratio in which the atoms have joined together. For example, the chemical formula for the covalent compound methane, a constituent of natural gas, is CH_4 — one carbon atom for every four hydrogen atoms. The formula for the ionic compound calcium chloride, which is used as a drying agent, is $CaCl_2$ — two chloride ions for every calcium ion.

5.8.3 Valency: formulae made easy

Knowledge of the **valency** of an element is essential if we wish to write formulae correctly.

The valency of an element is equal to the number of electrons that each atom needs to gain, lose or share to fill its outer shell. For example, the chlorine atom has only seven electrons in its outer shell, which can hold eight electrons. By gaining one electron, its outer shell becomes full. Chlorine therefore has a valency of one. The magnesium atom has two electrons in its outer shell. By losing two electrons, it is left with a full outer shell. Magnesium therefore has a valency of two.

A simple guide to remembering the valency of many elements is to remember to which group in the periodic table they belong. The number of outer-shell electrons allows you to work out the number of electrons required to fill the outer shell. The table at right provides a simple guide to the valency of many elements.

Valency of groups in the periodic table

Group	Valency
Group 1	1
Group 2	2
Group 3	3
Group 4, group 14	4
Group 15	3
Group 16	2
Group 17	1

5.8.4 Writing formulae for covalent compounds

To write the formula of a non-metal compound made up of only two elements, use the valency of each element and follow the steps shown below.

EXAMPLE 1

Write the formula for carbon dioxide.

Step 1 *Determine the valency of the elements involved.*

Carbon has a valency of four; oxygen a valency of two. (That is, carbon needs to share four electrons, while oxygen needs to share two electrons.)

Step 2 *Determine the ratio of atoms that need to combine so that each atom can share the same number of electrons.*

A ratio of one carbon atom to two oxygen atoms would result in both sharing four electrons.

Step 3 *Write the formula using the symbols of the elements and writing the ratios as subscripts next to the element. (The number '1' can be left out as writing the symbol for the element assumes that one atom is present.)*

The formula for carbon dioxide is CO_2.

EXAMPLE 2

Write the formula for phosphorus chloride.

Step 1 *Determine the valency of the elements involved.*

Phosphorus has a valency of three; chlorine has a valency of one.

Step 2 *Determine the ratio of atoms that need to combine so that each atom can share the same number of electrons.*

A ratio of one phosphorus atom to three chlorine atoms would result in both sharing three electrons.

Step 3 *Write the formula using the symbols of the elements and writing the ratios as subscripts next to the element.*

The formula for phosphorus chloride is PCl_3.

EXAMPLE 3

Write the formula for hydrogen oxide (water).

Step 1 *Determine the valency of the elements involved.*

Hydrogen has a valency of one; oxygen has a valency of two.

Step 2 *Determine the ratio of atoms that need to combine so that each element can share the same number of electrons.*

A ratio of two hydrogen atoms to one oxygen atom would result in both sharing two electrons.

Step 3 *Write the formula using the symbols of the elements and writing the ratios as subscripts next to the element.*

The formula for hydrogen oxide is H_2O.

5.8.5 Writing formulae for ionic compounds

The formulae for ionic compounds can be written from knowledge of the ions involved in making up the compound. In ionic compounds metal ions combine with non-metal ions. The tables on the next page list common positive and negative ions and their names.

Metal atoms usually form positive ions. The number of positive charges on the ion is called the **electrovalency** of the ion. For example, a sodium ion has one positive charge (Na^+), a calcium ion has two positive charges (Ca^{2+}) and an aluminium ion has three positive charges (Al^{3+}). Note that in the table at right some of the transition metals have more than one valency (e.g. iron). The Roman numerals in brackets after iron and copper identify the valency.

Non-metals usually form negative ions. The number of negative charges in the ion is the electrovalency of the ion. For example, chloride has one negative charge (Cl^-), oxide has two negative charges (O^{2-}) and phosphorus has three negative charges (P^{3-}). There are also some more complex negative ions called **molecular ions** or **radicals**, such as hydroxide ions (OH^-) and sulfate ions (SO_4^{2-}). These groups of atoms have an overall negative charge and are treated as a single entity. Note that the hydrogen ion, although a non-metal ion, exists as a positive ion.

Electrovalencies of some common positive ions

Number of positive charges in each element		
+1	+2	+3
Hydrogen (H^+)	Calcium (Ca^{2+})	Aluminium (Al^{3+})
Potassium (K^+)	Copper(II) (Cu^{2+})	Iron(III) (Fe^{3+})
Silver (Ag^+)	Iron(II) (Fe^{2+})	
Sodium (Na^+)	Lead (Pb^{2+})	
Ammonium (NH^{4+})	Magnesium (Mg^{2+})	
	Zinc (Zn^{2+})	

Electrovalencies of some common negative ions

Number of negative charges in each element		
–1	–2	–3
Bromide (Br^-)	Carbonate (CO_3^{2-})	Phosphate (PO_4^{3-})
Chloride (Cl^-)	Oxide (O^{2-})	Nitride (N^{3-})
Hydrogen carbonate (HCO_3^-)	Sulfate (SO_4^{2-})	
Hydroxide (OH^-)	Sulfide (S^{2-})	
Iodide (I^-)		
Nitrate (NO_3^-)		

The following examples show how the formulae for ionic compounds are determined.

EXAMPLE 1

Write the formula for aluminium oxide.

Step 1 *Determine the electrovalency of the ions that comprise the compound and write down their symbols.*

The symbol for the aluminium ion is Al^{3+} and the symbol for the oxide ion is O^{2-}.

Step 2 *Determine the ratio of ions required in order to achieve electrical neutrality. (Remember compounds have no overall charge.)*

The ratio of negative to positive charges for aluminium and oxide ions is 2:3. That is, it takes three negatively charged oxide ions to balance the charge of the two positively charged aluminium ions.

Step 3 *Write the formula for the compound using the numbers in the ratios as subscripts.*

The formula for the compound aluminium oxide is Al_2O_3.

EXAMPLE 2

Write the formula for sodium chloride.

Step 1 *Determine the electrovalency of the ions that comprise the compound and write down their symbols.*

The symbol for the sodium ion is Na^+ and the symbol for the chloride ion is Cl^-.

Step 2 *Determine the ratio of ions required in order to achieve electrical neutrality. (Remember compounds have no overall charge.)*

The ratio of negative to positive charges for sodium and chloride ions is 1:1. That is, it takes one negatively charged chloride ion to balance the charge of the positively charged sodium ion.

Step 3 *Write the formula for the compound using the numbers in the ratios as subscripts. (Remember the number '1' does not need to be included.)*

The formula for the compound is NaCl.

EXAMPLE 3

Write the formula for calcium phosphate.

Step 1 *Determine the electrovalency of the ions that comprise the compound and write down their symbols.*

The symbol for the calcium ion is Ca^{2+} and the symbol for the phosphate ion is PO_4^{3-}.

Step 2 *Determine the ratio of ions required in order to achieve electrical neutrality. (Remember compounds have no overall charge.)*

The ratio of negative to positive charges for calcium and phosphate ions is 3:2. That is, it takes two negatively charged phosphate ions to balance the charge of the three positively charged calcium ions.

Step 3 *Write the formula for the compound using the numbers in the ratios as subscripts.*

The formula for the compound calcium phosphate is $Ca_3(PO_4)_2$.

Note the use of brackets in the formula to show that more than one molecular ion is needed to balance the electrical charge.

INVESTIGATION 5.6

The ionic formula game

AIM: To practise deriving chemical formulae using chemical symbols of various anions and cations

You will need:

a set of playing cards with the name and valency of each of the positive and negative ions listed in the tables. You will need four identical cards for each ion.

- Organise a group of four students to play the card game. The aim of this game is to collect as many cards as possible by producing compounds with their correct chemical formulae.
- Shuffle the cards and then distribute them to the players.
- The dealer puts down one card.
- The rest of the players then try to produce a chemical formula using the cards they have in their hands. The first person to come up with a correct chemical formula wins the hand and keeps the cards. They are put aside until the end of the game. The dealer will decide the winner of the hand.
- The person to the left of the dealer then puts down one of their cards.
- The other players in the game now try to produce a chemical formula using the cards they have in their hands. Again, the person to come up with a correct chemical formula wins that hand and the cards are put aside until the end of the game.
- The game continues moving to the next person until no one is able to produce a chemical formula. The game stops at this point.
- Each player then counts the number of cards they have produced formulae with. The winner is the person with the most cards.

Discussion

1. Write a list of the formulae and the name of the compounds formed.
2. What is the best strategy to win the game?
3. Did you find the game useful in learning the formulae of compounds? Explain.

5.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** 'chemical formula'.
2. **Define** 'molecular formula'.
3. **Describe** what the formula of a compound tells you about the compound.
4. Write the symbols for the following elements: sodium, hydrogen, potassium, lead, chlorine, iodine and sulfur.

5. **Identify** which elements are present in each of the following compounds.
   (a) HNO_3
   (b) $NaHCO_3$
   (c) FeS
6. **Recall** how the valency of an element is determined.
7. **Calculate** how many chloride (Cl^-) ions would be required to combine with each of the following ions to form an ionic compound.
   (a) Calcium (Ca^{2+})
   (b) Aluminium (Al^{3+})
   (c) Silver (Ag^+)
8. Write down the valencies for the following elements: sodium, hydrogen, lead, chlorine, iodine, magnesium and sulfur.

Think

9. The ions listed below can combine in many different ways to form 25 different compounds. Write the formulae and names of these compounds.
   Na^+ Fe^{3+} Li^+ Cu^{2+} Al^{3+} Cl^- OH^- N^{3-} O_2^- SO_4^{2-}
10. The chloride ion has the same valency as the sodium ion. However, it has a different electrovalency. **Explain** why.
11. Write a formula for each of the following:
    (a) Oxygen gas
    (b) Chlorine gas
    (c) Lead
    (d) Nitrogen oxide
    (e) Zinc oxide
    (f) Potassium sulfate
    (g) Calcium hydroxide
12. Name the following compounds.
    (a) NH_4Cl
    (b) KI
    (c) $Al(NO_3)_3$
    (d) Fe(OH)
    (e) $KHCO_3$
    (f) $MgCO_3$
    (g) HNO_3
13. **Explain** why group 18 is not listed in the valency table.

Imagine

14. Imagine that there was no recognised system for naming elements and compounds. **Describe** some of the problems this would lead to.

Create

15. **Construct** your own ionic compound formula game. It could be an improved version of the game in Investigation 5.6. However, it does not have to be a card game.

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Complete this digital doc: Worksheet 5.7: Chemical formulae (doc-12767)

5.9 Project: The mystery metal

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5.9.1 The mystery metal

Scenario

Your eccentric aunt loves combing through junk shops in search of overlooked treasures, and every time you spend a day with her she'll make you go into one grubby store smelling of mangy mink coats after another. One day during the school holidays, you are wandering idly in one of these old junk shops while your aunt haggles for an old vase with the owner. You find a lump of metal in a drawer of an old dresser. The shopkeeper says that you can keep it and you put it in your pocket. Occasionally over the next few days you wonder what the metal is. Is it something valuable like platinum, or useful like aluminium? Or is it just an old lump of lead? By the end of the holidays, you've forgotten all about the lump of mystery metal.

When you get back to school, your science teacher announces that everyone in your class is to enter a competition that the Australian Chemistry Teachers' Association is running. The competition needs you to write an online 'Choose your own adventure' story that has a chemistry theme. You and your friends are scratching your heads trying to come up with an idea when, suddenly, you remember that lump of mystery metal you found in the junk shop. Maybe you could use that as the theme for your competition entry . . .

Your task

Either on your own or as part of a group, you will develop a 'Choose your own adventure' (CYOA) story exploring the identification of the mystery metal. You will then create a series of interconnected PowerPoint screens that can be uploaded. A player starting at the first screen will advance through a storyline according to the choices they make at each screen. The choices will relate to various chemical and physical characteristics of the metal. The right sequence of choices will eventually lead to the correct identification of the mystery metal.

Process

- You can complete this project individually or invite other members of your class to form a group.
- Start your research. Make notes of information that you think will be relevant to your project, such as what different metals look like and how metals that look similar can be distinguished from one another. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about the chemistry of metals.

5.10 Review

5.10.1 Atomic theory

- **describe** the features and location of protons, neutrons and electrons in an atom 5.2
- **define** the terms 'ion', 'electron cloud' and 'molecule' 5.2, 5.3, 5.4
- **distinguish** between atomic mass and atomic number 5.3, 5.4
- **describe** the way in which electrons are arranged around the nucleus 5.2, 5.3, 5.4

5.10.2 Elements and compounds

- **describe** some relationships between elements using the periodic table 5.4
- **compare** the shell arrangements and properties within atoms in different groups in the periodic table 5.5
- **distinguish** between elements and compounds 5.6
- **define** the term 'valency' 5.8
- **identify** features of specific families of elements 5.4
- **explain** how compounds are named 5.6, 5.7, 5.8

5.10.3 Bonds between atoms

- **distinguish** between ionic and covalent bonds 5.7, 5.8
- **identify** which compounds are more likely to have one form of bond rather than another 5.7, 5.8
- **compare** and **contrast** characteristics of ionic and covalent compounds 5.6, 5.7
- **recall** how electron dot diagrams can be used to represent bonds 5.5, 5.6

5.10.4 History of science

- **discuss** how the model of an atom's structure has changed over the last two thousand years 5.2, 5.3

Individual pathways

ACTIVITY 5.1	ACTIVITY 5.2	ACTIVITY 5.3
Revising chemistry	Investigating chemistry	Investigating chemistry further
doc-10647	doc-10648	doc-10649

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FOCUS ACTIVITY

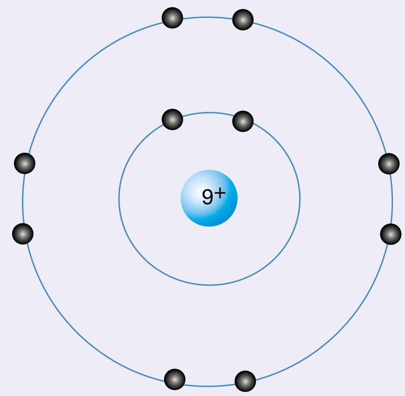
online only

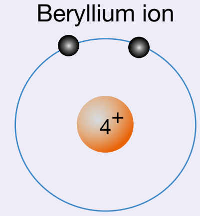
Explain how the periodic table has been helpful to chemists of both the past and present when they are searching for new elements.
Access more details about focus activities for this topic in the Resources tab (doc-10646).

assesson

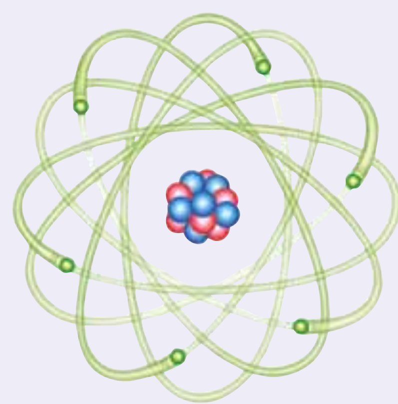
5.10 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.



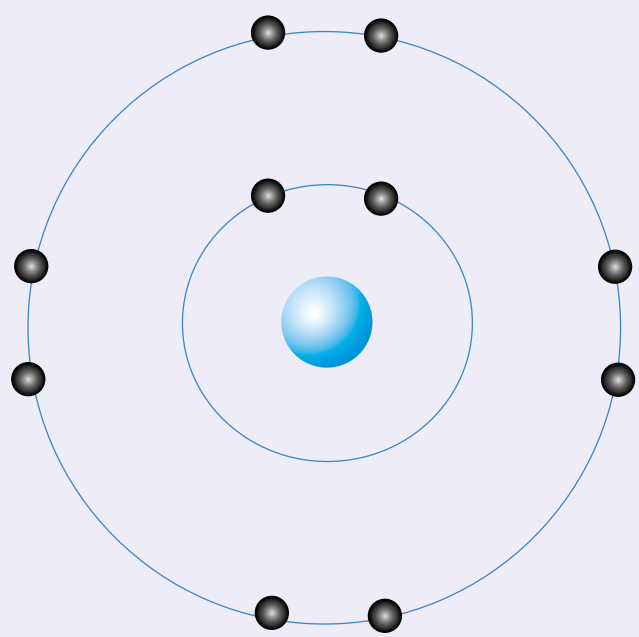


1. In what part of an atom is most of its mass contained?
2. **Identify** the force that holds protons and neutrons together in an atom's nucleus.
3. (a) **Describe** the 'plum pudding' model of the atom.
   (b) How was this model different from the 'planetary' model of the atom?
   (c) Who first described the atom as being indivisible?
4. A neon atom has 10 protons. **Calculate**:
   (a) how many electrons there are in total in a neutral neon atom
   (b) how many electrons there are in the first shell of a neutral neon atom
   (c) how many electrons there are in the outer shell of a neutral neon atom.
5. Draw an electron shell diagram of a neon atom.
6. **Explain** the difference between atoms, molecules and ions by drawing an example of each.
7. **Recall** the charge on:
   (a) a proton
   (b) a neutron
   (c) an electron
   (d) a sodium ion.
8. **Identify** which of the diagrams above right represents a:
   (a) positive ion
   (b) negative ion.
9. The diagram at right represents a model of a neutral atom.
   (a) **Recall** which two types of particle make up the nucleus of the atom.
   (b) **Identify** the particles shown orbiting the nucleus in the atom.
   (c) What features of an atom are not very well represented by this particular model?
   (d) **Identify** the element that this diagram represents.



10. Write the atomic number and mass number of the following atoms and then calculate the number of protons, neutrons and electrons they have.
   (a) ${}^{28}_{14}\text{Si}$
   (b) ${}^{52}_{24}\text{Cr}$
   (c) ${}^{197}_{79}\text{Au}$
   (d) ${}^{206}_{82}\text{Pb}$
   (e) ${}^{242}_{94}\text{Pu}$

11. Use the ${}^{A}_{Z}E$ convention to write the symbols for the following elements:
    (a) Helium
    (b) Molybdenum
    (c) Meitnerium
12. The periodic table is a classification of all the known elements. **Describe** what information is given by the group and period numbers on the periodic table.
13. **Recall** the group of elements in the periodic table that the neon used in lighting belongs to.
14. As you move down the groups in the periodic table, **describe** how the reactivity changes for:
    (a) metals
    (b) non-metals.
15. As you move across the periodic table, **describe** what changes occur in:
    (a) atomic number
    (b) mass number
    (c) melting point
    (d) metallic character.
16. Although they look very different from each other and have very different uses, arsenic, germanium and silicon belong to the group of elements known as metalloids. **Explain** how metalloids differ from all of the other elements in the periodic table.
17. Write the electron arrangements for the following atoms: helium, silicon, argon, potassium, phosphorus.
18. All atoms of the element magnesium have twelve protons. Eighty per cent of those atoms have twelve neutrons.
    (a) State the atomic number of magnesium.
    (b) What is the mass number of most magnesium atoms?
    (c) How many electrons orbit a neutral magnesium atom?
    (d) **Explain** why all magnesium atoms don't have the same mass number.
19. The electron shell diagram at right has its first two shells filled. It could represent a neutral atom, a positive ion or a negative ion. **Identify** the names and symbols of the atom or ion if it represents:
    (a) a neutral atom (identify one)
    (b) a positive ion (identify two possibilities)
    (c) a negative ion (identify two possibilities).



20. Use diagrams to show how the following ionic compounds form.
    (a) Lithium fluoride (LiF)
    (b) Sodium oxide (Na_2O)
21. Use diagrams to show how the following covalent compounds form.
    (a) Hydrogen chloride (HCl)
    (b) Ammonia (NH_3)
22. **Compare** the properties of ionic and covalent compounds.
23. Write formulae for the following substances:
    (a) Oxygen gas
    (b) Carbon dioxide gas
    (c) Aluminium oxide
    (d) Sodium fluoride
    (e) Calcium carbonate
    (f) Zinc chloride
    (g) Iron (III) sulfide
    (h) Sulfur dioxide
    (i) Carbon
    (j) Lead

Test yourself

1. Every element in the periodic table has an atomic number. The atomic number of an element refers to the number of
   (A) electrons in its outermost shell.
   (B) electrons in all of its shells.
   (C) neutrons in its nucleus.
   (D) protons in its outermost shell.

(1 mark)

2. An aluminium atom has 13 protons in its nucleus. On the periodic table, aluminium is in
   (A) group 2, period 2.
   (B) group 3, period 3.
   (C) group 4, period 3.
   (D) group 3, period 2. **(1 mark)**
3. An atom with two electron shells and six electrons in the outermost shell is
   (A) magnesium.
   (B) calcium.
   (C) nitrogen.
   (D) oxygen. **(1 mark)**
4. A molecular bond in which atoms share electrons is called a(n)
   (A) ionic bond.
   (B) covalent bond
   (C) metallic bond.
   (D) aqueous bond. **(1 mark)**
5. There have been many occasions in chemistry when a new substance has been discovered quite by accident. Such a substance was discovered in the 1930s when chemists opened a gas tank. Imagine their surprise when, instead of finding a gas, they found a white solid. The chemists investigated the solid and found it
   - did not conduct electricity
   - was very slippery to touch
   - was tough and didn't shatter
   - softened at 320°C
   - did not dissolve in water.

   The accidently discovered substance was most likely made up of
   (A) small molecules where the atoms share electrons.
   (B) large molecules where the atoms share electrons.
   (C) a network of atoms that share electrons with the atoms around them.
   (D) metal ions and electrons in a metal lattice.
   (E) a lattice of positive and negative ions. **(3 mark)**
   Justify your choice with a full explanation.

   (This unexpected discovery is, today, used to make many things, including the surfaces of skis and frypans.)

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Complete this digital doc: Worksheet 5.8: Chemistry — the inside story: puzzles (doc-12768)

Complete this digital doc: Worksheet 5.9: Chemistry — the inside story: summary (doc-12769)

TOPIC 6
Radioactivity: a two-edged sword

6.1 Overview

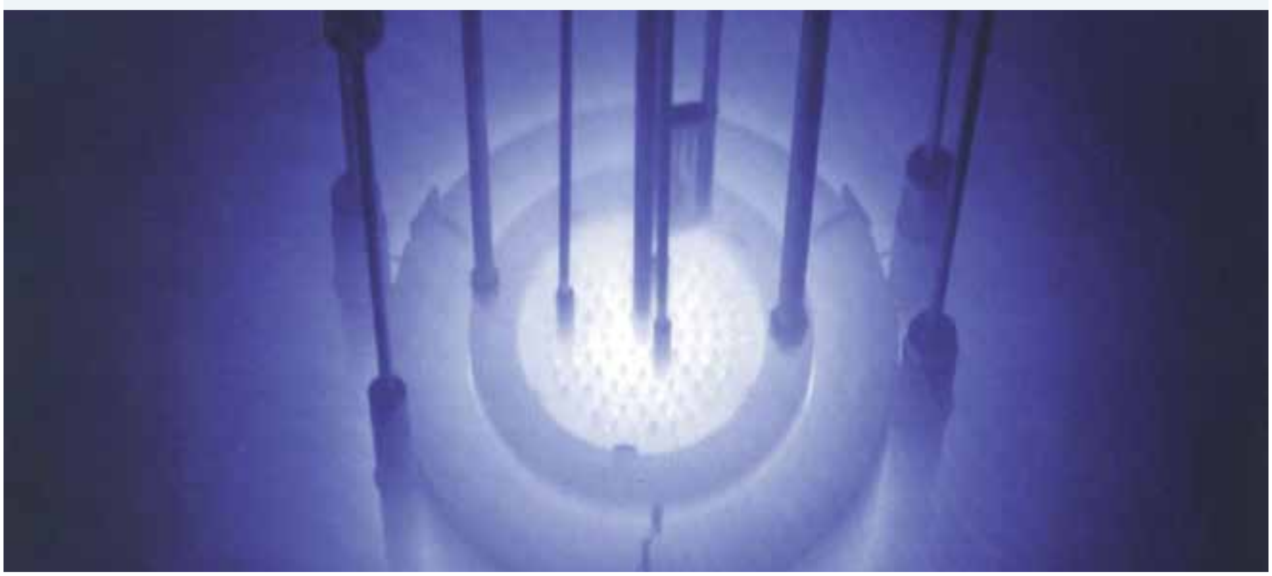
Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

6.1.1 Why learn this?

When most people hear the word 'radioactivity', they immediately conjure up mental images of scientists in lead suits holding ticking Geiger counters out in front of them, or of the horrible burns or cancers suffered by survivors of atomic bombs or the Chernobyl disaster. But destruction is not all that there is to radioactivity. It can also be a valuable lifesaver and scientific tool.

LEARNING SEQUENCE

The movement of charged particles travelling through the water around this nuclear reactor core causes the water molecules around them to gain energy. The atoms in the water molecules release this extra energy in the form of light at the blue end of the spectrum. This causes the blue glow around the core called the Cherenkov Effect.



To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Superpowers for everybody?
   If the comics, TV and movies are to be believed, being hit with radiation can give you superpowers!
   (a) List as many superheroes that you can who owed their powers to radiation or radioactivity. What powers did they have?
   (b) Can radioactivity exposure actually cause mutation? Explain using examples.
   (c) What is radiation sickness? What are its symptoms?
   (d) How much radiation can a human be exposed to before they get radiation sickness?

2. The element of surprise!
   Complete the table below, but be careful — you may need a periodic table and some thought!

Element	Number of protons	Number of neutrons	Atomic mass
Carbon	6		12
		8	14
	7		14
	17	20	
	92		235
	92		238
	18		40
	1	2	
		2	3

3. Cloud of doom?
   Consider the image at right.
   (a) What name is given to clouds like this?
   (b) What causes them to form?
   (c) How high into the sky do you think the top of the cloud reaches?
   (d) What is the cloud made of?

4. Who's who?
   Find out who each of the following elements were named for and what their contribution was to our understanding of radioactivity: meitnerium; curium; rutherfordium; fermium; einsteinium; roentgenium; bohrium.

6.2 Pioneers of radiation

6.2.1 Wilhelm Roentgen (German scientist, 1845–1923)

While nuclear power stations and MRI machines are all very much inventions of the twentieth century, the foundations of nuclear physics actually lie in the late nineteenth century. Without the pioneering work of scientists such as Wilhelm Roentgen, Henri Becquerel and the Curies, chances are that many of the technologies that we now take for granted would not have been developed.

In November 1895, the German scientist Wilhelm Roentgen was using a Crookes tube (see next page) in a series of experiments. He found that, even when the tube was completely covered in thick black cardboard to prevent visible light escaping, a nearby screen coated in barium platinocyanide glowed when the Crookes tube was turned on and the voltage was high. Roentgen quickly determined that this glow was not caused by cathode rays and reasoned that the Crookes tube was producing some other sort of invisible rays which were able to travel through the cardboard to the screen. He named these mysterious rays **X-rays**. Later experiments showed him that the X-rays could travel through low density substances such as cardboard and human flesh, but were blocked by denser substances such as metals and bone.

Wilhelm Roentgen

The first X-ray

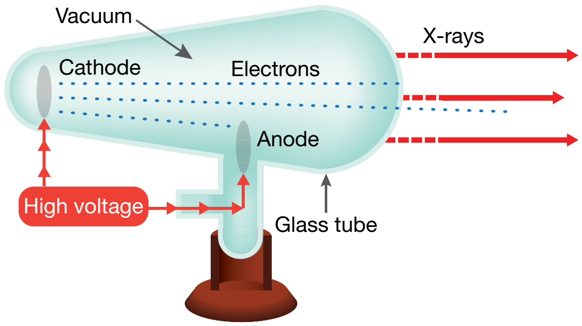
Less than a month after his first discovery of X-rays, Roentgen demonstrated their usefulness for medical diagnosis by producing an X-ray image of his wife's hand which clearly showed the bones inside as well as the ring that she wore, yet not the skin, sinews, muscles or veins.

The first X-ray

6.2.2 How it works — the Crookes tube

Invented by English scientist William Crookes in the 1870s, a Crookes tube is made up of a glass tube with most of the air removed from inside it to form a vacuum. It contains two plates — the anode and the cathode. When the plates are connected to a voltage source, the end of the tube glows **(fluoresces)**. Scientists of Crookes' time believed that this glow was caused by rays travelling from the cathode and overshooting the anode. Later, J. J. Thomson realised that these 'cathode rays' were actually negatively charged parts of atoms which he eventually named electrons.

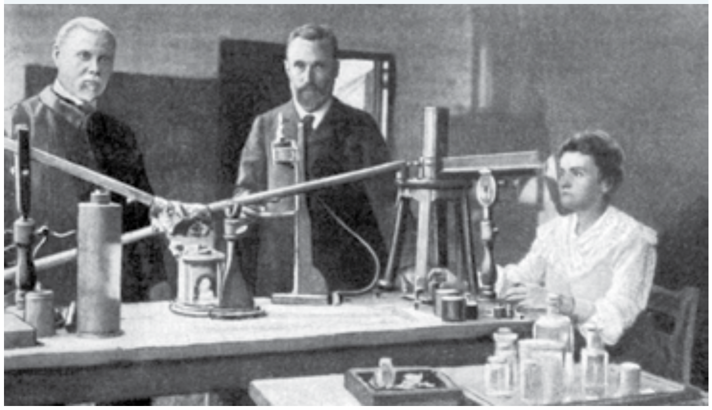
A Crookes tube



6.2.3 Henri Becquerel (French scientist, 1852–1908)

Becquerel was excited by Roentgen's discovery of X-rays as it gave new insights into his own studies at the time into the phenomenon of fluorescence. He found that some substances would glow if they were exposed to an energy source such as X-rays or even sunlight. When the energy source was removed, the substance stopped glowing. One day in 1896, Becquerel discovered that some covered photographic plates had been exposed when kept in a dark drawer with uranium ore samples in it. As there were no energy sources in the drawer, Becquerel reasoned that the uranium must have been producing some sort of invisible rays that had exposed the plates.

(From left) Henri Becquerel, Pierre Curie and Marie Sklodowska-Curie



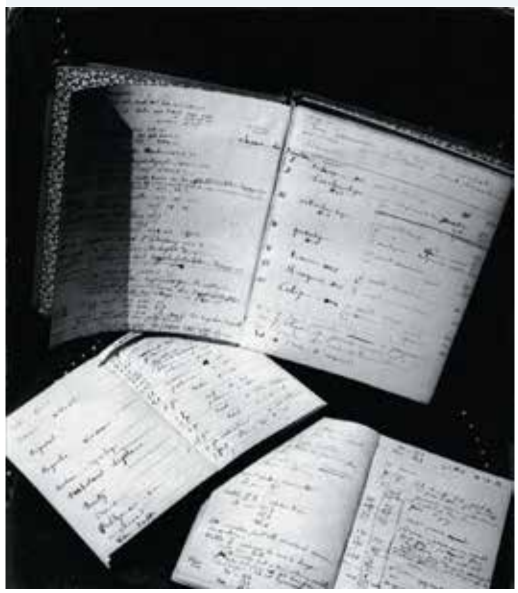
6.2.4 Marie Sklodowska-Curie (Polish/French scientist, 1867–1934) and Pierre Curie (French scientist, 1859–1906)

The Curies came to work with Becquerel, investigating the invisible rays that his uranium samples had produced. They found that the rays produced by uranium ores caused the air particles around them to become ionised. They referred to the rate at which the ionisation occurred as **activity** and the substances that produced this activity as being **radioactive**.

While experimenting with a uranium-containing mineral called **pitchblende**, they found that material remaining from the ore was much more radioactive than the pure uranium that had been removed from it. They reasoned that there was another element in the mineral that they named **polonium** after Marie's country of birth. After many years, the Curies found another element, which they called **radium**, which had similar properties to polonium. It took four years of processing tons of pitchblende to get enough of each of these new elements to determine their chemical properties!

Marie and Pierre Curie and Henri Becquerel were jointly awarded the 1903 Nobel Prize for Physics for their discovery of radioactivity.

Marie Curie's laboratory notebooks, today stored at the Bibliothèque Nationale in Paris, can be viewed from behind thick glass but are still so radioactive that they cannot be touched or handled without wearing proper protection.



HOW ABOUT THAT!

Marie Curie was the first woman to be awarded a Nobel Prize. After Pierre's death, Marie continued her studies into radioactivity and was awarded the 1911 Nobel Prize for Chemistry for her discovery of the elements polonium and radium, and for her work in unravelling the properties of radioactive elements. She was the first person in the award's history to receive two Nobel prizes yet, because of the attitudes of the scientific community towards women at the time, the French Academy of Sciences refused to allow her to become a member.

6.2.5 Ernest Rutherford (New Zealand scientist, 1871–1937)

Interested by the findings of Becquerel, Ernest Rutherford began to investigate the radiation produced by uranium ore. Like Becquerel, he originally assumed that these rays were similar to cathode rays. However, his experiments led him to conclude that at least two different types of rays were being produced which had different penetrating power. He named the rays that were easily blocked or absorbed **alpha (α)** and the more penetrating rays were referred to as **beta (β)**. By 1901, he determined that the alpha and beta rays were in fact made up of streams of charged particles which became known as alpha and beta particles. Rutherford further determined that alpha particles were positively charged helium nuclei while beta particles were negatively charged electrons. When passed through a magnetic field, the charge on the particles interacted with the magnetic field in such a way that the paths of alpha particles entering the field would curve in one direction while those of beta particles would curve in the other. It was this distinguishing feature that allowed Paul Villard to make the next big discovery.

Ernest Rutherford

6.2.6 Paul Villard (French scientist, 1860–1934)

At the same time that Rutherford was investigating the nature of the radiation produced by uranium, Paul Villard studied the radiation produced by the element radium, which had been newly isolated by the Curies. He passed the radium radiation through a thin layer of lead which had been shown by Rutherford to stop alpha rays. Rutherford had also earlier found that, in a magnetic field, the path of alpha rays would curve in one direction while beta rays curved in the other.

In Villard's experiments the radiation passing through the lead was sent through a magnetic field where he found that, while some of the rays (later found to be beta rays) did indeed curve, the rest of the radiation continued travelling in a straight line, unaffected by the magnetic field.

Rutherford suggested that Villard's rays should be named gamma (γ) rays when it was found that they were far more penetrating than the alpha rays and beta rays which he had discovered. Villard found that the gamma rays were similar in nature to Roentgen's X-rays. In 1913, it was confirmed that gamma rays and X-rays were both forms of electromagnetic radiation.

Paul Villard

6.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Explain** how X-ray images are formed.
2. What does radioactive mean?
3. Name the radioactive elements discovered by the Curies.
4. **Describe** at least two applications for X-rays.
5. What is fluorescence?
6. How did the Curies know that there was another radioactive substance in pitchblende apart from uranium?
7. In what ways are gamma, beta and alpha radiation different?

Think

8. In the first X-ray image produced by Roentgen, the ring on his wife's hand can be clearly seen but the skin on her hand is invisible. Why is this?

Investigate

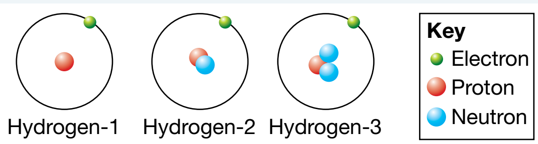
9. Find out how fluorescence is different from phosphorescence. Which of these is demonstrated by glow-in-the-dark stickers?
10. Marie and Pierre Curie's daughter Irene also won a Nobel prize. Find out (a) who she shared it with, (b) what it was won for and (c) in what year it was awarded.

6.3 Radioactive isotopes

6.3.1 Isotopes

As you may remember from topic 5, all atoms of the same element have the same number of protons — in other words, they have the same atomic number. However, while the atoms of a particular element have the same number of protons, they may not always have the same number of neutrons in their nuclei. For example, the normal version of hydrogen has a single proton in its nucleus but another naturally occurring version of hydrogen (called hydrogen-2 or **deuterium**) has a proton and a neutron in its nucleus, and yet another version (called hydrogen-3 or **tritium**) has a proton and 2 neutrons.

The three isotopes of hydrogen. Hydrogen-2 and hydrogen-3 are also known as deuterium and tritium respectively.



Atoms that have the same number of protons but differ in number of neutrons are called **isotopes**. Most elements have 2 or 3 different isotope forms. The isotopes of an element have the same chemical properties — they just differ in mass number. Remember, the mass number of an atom is equal to the number of protons and neutrons in its nucleus.

As you will remember from topic 5, the symbol for an isotope is written as ${}^{A}_{Z}E$ where

A = mass number = number of protons + number of neutrons
Z = atomic number = number of protons
E is the chemical symbol for the element.

So, while the most common isotope of carbon (which has 6 protons and 6 neutrons) is written as ${}^{12}_{6}C$, the isotope carbon-14 (which has 6 protons but 8 neutrons) is written as ${}^{14}_{6}C$.

6.3.2 Radioactive isotopes

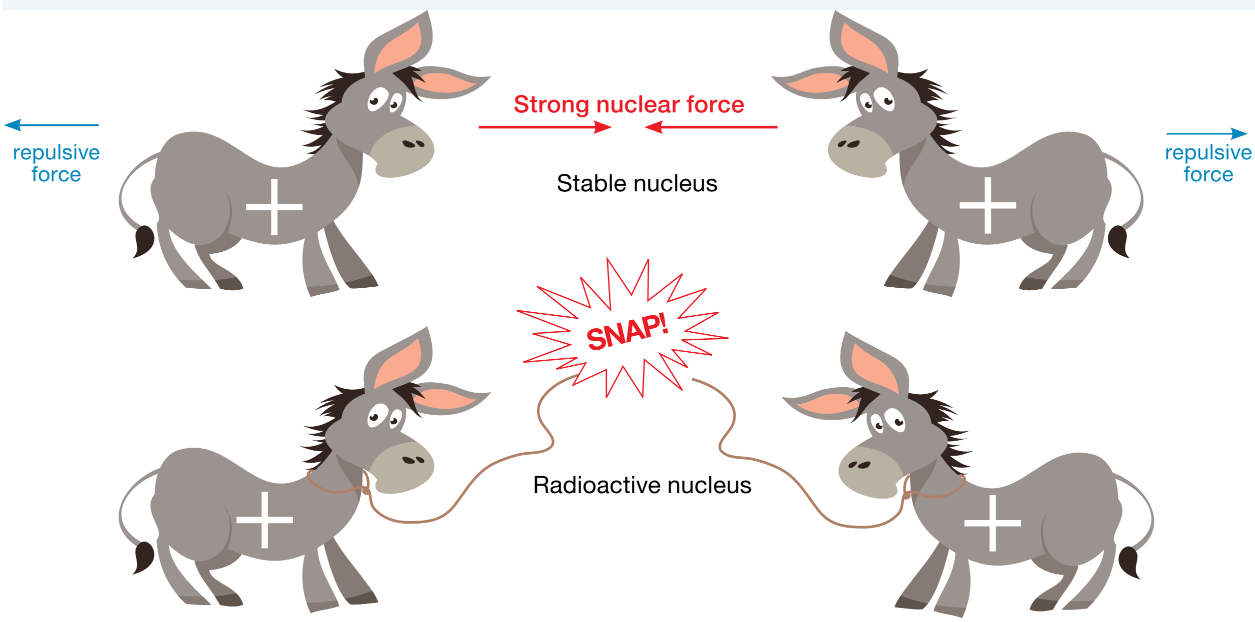
The protons and neutrons of the nucleus are held tightly together by something called the **strong nuclear force**. Without the strong nuclear force, the repulsive force between the positively charged protons would tear the nucleus apart. In most isotopes, the repulsive force and the strong nuclear force balance out and the nucleus remains intact, or **stable**.

In some isotopes, however, the extra neutrons in the nucleus make it much harder for the strong nuclear force to keep the nucleus together and the nucleus breaks apart or **decays**. When an unstable nucleus breaks up, energy in the form of **radiation** is released and smaller, more stable elements are formed. As a result, isotopes whose nuclei have a tendency to decay are said to be radioactive.

This suit protects its wearer against something that can't be seen, touched or heard.

Element	Symbol	Number of protons	Number of neutrons	Stable or radioactive?
Carbon-12	${}^{12}_{6}C$	6	6	Stable
Carbon-14	${}^{14}_{6}C$	6	8	Radioactive
Uranium-235	${}^{235}_{92}U$	92	143	Radioactive
Uranium-238	${}^{238}_{92}U$	92	146	Stable

In stable isotopes, the strong nuclear force is stronger than the repulsive force between the protons in the nucleus. In radioactive isotopes, the repulsive force is stronger and the nucleus breaks apart, releasing radiation.



6.3.3 The half-life

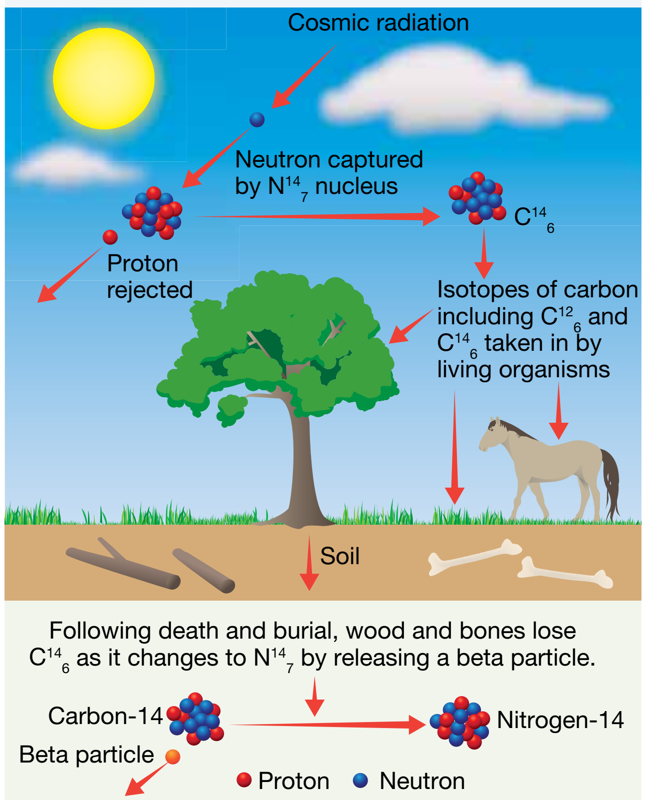
When an atom of a radioactive isotope decays, it releases radiation and forms a different, usually lighter nucleus. The rate at which these isotopes decay is described by its **half-life** — the time you would need to wait for half of the amount of the radioactive material to decay. For example, carbon-14 has a half-life of 5700 years. If you had a 1 kg lump of carbon-14, after 5700 years had elapsed, only 500 g would still be carbon-14. The other 500 g would have decayed to form the stable isotope nitrogen-14 (we say that nitrogen-14 is the **daughter isotope** of carbon-14). After 11 400 years, you would have only 250 g of carbon-14 and after 16 100 years only 125 g of the carbon-14 would be left. The following table shows the decay of carbon-14.

Time elapsed (years)	Amount of carbon-14 present (g)	Fraction of starting amount remaining
0	1000	1
5 700	500	1/2
11 400	250	1/4
16 100	125	1/8
21 800	62.5	1/16

Some radioactive materials decay at faster rates than others. Many of the substances used in cancer treatments have half-lives of only a few hours, while uranium-238 has a half-life of 4.5 billion years!

6.3.4 Radiocarbon dating

Radioactive carbon-14 is absorbed by all living things. When the organism dies, the carbon-14 in the organism decays over time.



The decay of carbon-14 is a particularly useful tool for archaeologists and anthropologists who wish to determine how old an organic relic is. This is done by considering how much carbon-14 is in the relic.

Carbon-14 is produced in the Earth's atmosphere when cosmic rays strike nitrogen-14 atoms. All living things take in carbon including radioactive carbon-14 throughout their lives. New carbon-14 is taken in to replace the carbon-14 that decays, so the total amount of carbon-14 in an organism stays constant while it is alive. When an organism dies, however, no new carbon-14 is taken in so the amount of carbon-14 in the organism's remains decreases over time.

When scientists find the preserved organism, they measure the amounts of carbon-12 and carbon-14 in a sample of the organism. The ratio of carbon-14 to carbon-12 is fairly standard in a living organism (about one carbon-14 atom for every trillion carbon-12 atoms). As the amount of carbon-12 in the sample remains nearly constant over time, it is then possible to work backwards and estimate the amount of carbon-14 that the sample would have originally had. This original amount is then compared to the amount of carbon-14 remaining in the organism's preserved body. This allows the scientists to work out how many half-lives of carbon-14 have elapsed since the creature died and, as the half-life is known, an approximate time of death for the organism can be determined. For example, if the organism has only half the amount of carbon-14 that would be expected, it has been dead for 1 half-life; i.e. about 5700 years. Carbon-14 dating can be unreliable, however, if the specimen is contaminated with other organic matter.

Sample being removed from bone for carbon dating using accelerator mass spectrometry (AMS). The bone is a human femur that is thought to date to the Middle Ages.

INVESTIGATION 6.1

Simulating radioactive decay

AIM: To model radioactive decay

You will need:

100 M&Ms
clean sheet of white paper
large plastic container
plastic gloves or very well-scrubbed hands

- First make a copy of the table below in your notebook.

Turn	Number of M&Ms in container at start of turn	Number of M&Ms that 'decayed' this turn	Total number of M&Ms 'decayed' since the start	% of M&Ms that have decayed since the start	% of M&Ms remaining from the start
1	100				
2					
3					
4					
5					
6					

- Lay out all the M&Ms on the sheet of paper with the 'M' side down. This represents all of the atoms in the parent isotope before radioactive decay occurs.
- Place all of the M&Ms into the plastic container and shake them thoroughly. The M&Ms should be able to move around freely in the container. Pour the M&Ms onto the paper again and spread them out *without changing which side up each one has landed.*
- Separate out the M&Ms that have landed with the 'M' facing upwards. These represent the atoms that have decayed into a new isotope. Count how many of these there are and enter the amount in the table. Place these to one side.
- Collect the remaining M&Ms (the ones that landed 'M' side down) and return them to the container. Shake the container, pour out the M&Ms and repeat the previous step.
- Continue in this way until all of the M&Ms have been removed. You may need more rows in your data table than have been shown.

Discussion

1. Plot your results as a line graph with the turn number on the horizontal axis and the percentage of 'undecayed' M&Ms remaining at the end of the turn on the vertical axis.
2. Compare your group's results with the other groups in your class. Did you all get similar results? Explain why there would be some variation.
3. Your teacher will combine the class results. Plot these results on a line graph using the same axes as you used in question 1. Compare this graph shape to the one that you drew earlier.
4. Looking at your combined results, describe the general relationship between the turn number and the percentage of undecayed M&Ms left at the end of the turn.

Dating rocks

Radiocarbon dating can only be done on things that were once part of living organisms. As a result, you can't use it to work out how old a rock is. Instead, the decay of other isotopes can be used to date rocks. One of the most widely used systems looks at the decay of uranium isotopes in zircon, which is a mineral common to many rocks.

Uranium-235 has a half-life of 704 million years and it decays to form an isotope of lead $\left({}^{207}_{82}\mathrm{Pb}\right)$. By comparing the amounts of lead-207 and uranium-235 a rock sample containing zircon has in it, the age of the rock can be estimated.

6.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. In the symbol ${}^{A}_{Z}E$, what is represented by (a) the letter A (b) the letter Z?
2. **Calculate** the number of (a) protons (b) electrons (c) neutrons in:
   (a) ${}^{235}_{92}\mathrm{U}$
   (b) carbon-13
   (c) hydrogen-2.
3. How do isotopes of the same element differ from each other?
4. **Explain** why the isotopes of some elements are radioactive.
5. What do the terms (a) half-life (b) daughter isotope (c) radiocarbon mean?
6. Why can't radiocarbon dating be used to determine the age of a rock?

Think

7. The half-life for a radioactive isotope X is 2 hours.
   (a) If you had 500 g of isotope X, how much would remain after (i) 2 hours (ii) 8 hours?
   (b) How long will it take until only 125 g of isotope X is left?
8. The Earth is estimated to be about 4.5 billion years old. How much uranium-235 would there have been when the Earth was formed compared to how much there presently is?
9. About 0.01 per cent of the potassium in your body is the radioisotope ${}^{40}_{19}\mathrm{K}$.
   (a) How many protons and neutrons are in each atom of this radioisotope?
   (b) The stable nuclei of potassium atoms have one less neutron than the nuclei of potassium's unstable radioisotope. Write down the complete symbol for the stable isotope of potassium.
10. Are the atoms ${}^{230}_{93}\mathrm{X}$ and ${}^{230}_{94}\mathrm{Y}$ isotopes of the same element? **Explain**.
11. The half-life of tritium is 4500 days. How many days will it take an amount of tritium to fall to a quarter of its initial mass?
12. Parts of the skeleton of a large animal are found buried in sand dunes. The amount of radioactive carbon-14 in the bones is about one-eighth of that found in the skeletons of living animals. How long ago did the animal probably die (to the nearest thousand years)?

13. Approximately what percentage of the original amount of radioactive carbon-14 would you expect to find in:
    (a) an Aboriginal spear 11 000 years old?
    (b) a skull 23 000 years old, found in a cave?

Using data

14. Graph the decay of carbon-14 by using the data in the table. You will need to have the time in days on the horizontal axis and the amount of carbon-14 remaining in grams on the vertical axis. Use your graph to approximate:
    (a) the amount of carbon-14 left after 8000 years
    (b) how long it takes for there to be 300 g of carbon-14 remaining.

Investigate

15. Find out which radioactive gas in the atmosphere is responsible for most of the background radiation we are exposed to on Earth.
16. While radiocarbon dating is very useful for determining the age of relics that have organic material in them, it can be used only for relics of particular ages. Find out what the age limitations on radiocarbon dating are and the cause of these limitations.

6.4 Radiation

6.4.1 Types of radiation

When radioactive substances decay to form more stable nuclei, their nuclei release energy in the form of **nuclear radiation**. As Rutherford and his contemporaries found early in the twentieth century, there are three types of nuclear radiation: alpha (α), beta (β) and gamma (γ).

6.4.2 Background radiation

Every day, we are all exposed to low levels of radiation from a variety of natural and artificial sources. These sources include the radiation released by the decay of isotopes in the Earth's crust, the cosmic radiation that reaches us from the sun and even radiation from buildings which are made from naturally radioactive materials in clay bricks or granite. This constant low-level radiation that surrounds us is called **background radiation** and is harmless to us.

6.4.3 Ionising radiation

Alpha, beta and gamma radiation are all forms of ionising radiation because of their ability to pull electrons from nearby atoms and molecules, turning them into ions. Exposure to ionising radiation can cause damage to living body tissue. Long-term exposure to low amounts or 'doses' can cause DNA damage, cancer and tumour growth, while high doses in a short period of time can cause burns, nausea, destruction of bone marrow and blood cells, and death.

The effect that ionising radiation has on the human body depends upon a number of different things including:

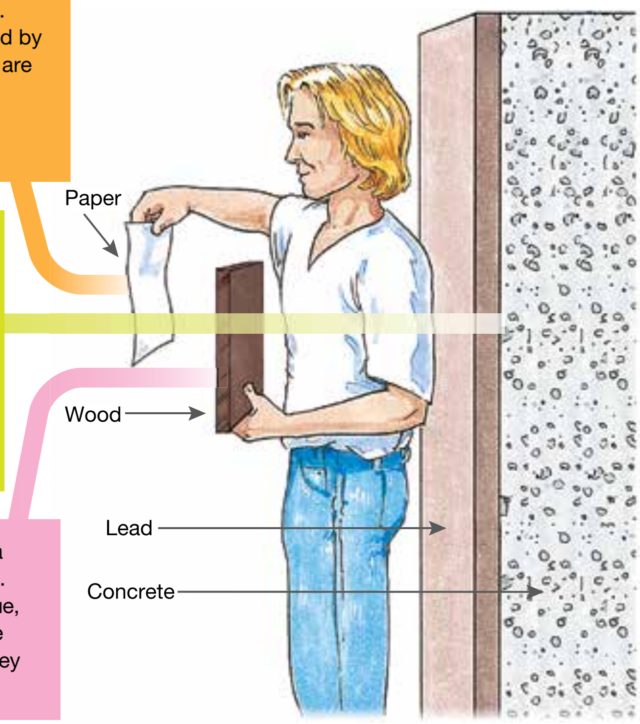
- the mass of the person
- amount/period of exposure to the radiation
- type of radiation
- radioactivity of the material
- rate at which the radiation is received
- presence of shielding material that could absorb some of the radiation
- distance from the radiation source.

The different penetrating powers of alpha (α), beta (β) and gamma (γ) radiation

Alpha particles are streams of helium nuclei. These particles are the largest of the radiation particles and move relatively slowly. They cannot travel easily through materials and can be stopped by a few centimetres of air, a sheet of paper or human skin. They are of little danger to the outside of the body but they can cause serious damage if breathed in, eaten or injected. They are produced by the heavier radioactive elements.

Gamma rays are made up of electromagnetic waves (as are radio waves and microwaves) rather than particles. Gamma rays have no mass and travel at the speed of light. They have a lot more penetrating power than alpha or beta particles and can be stopped only by a thick shield of lead or concrete. As they pass through the body, they can cause serious and permanent damage to the living tissue and the DNA of the cells themselves. Gamma rays are produced along with alpha and beta particles.

Beta particles are fast-moving electrons. Smaller than the alpha particles, beta particles travel at 99 per cent of the speed of light. Beta particles can penetrate human skin and damage living tissue, but they can be absorbed by 100 cm of air and cannot penetrate thin layers of aluminium or centimetres-thick plastic or wood. They are produced by the lighter radioactive elements.



Measuring radiation doses

When a person is exposed to radiation, energy is deposited in the tissues of the body. The average amount of energy in joules absorbed per kilogram of body mass is referred to as the **absorbed dose** (D). The unit of absorbed dose is the **sievert (Sv)**:

$$\mathbf{D = \frac{energy\ absorbed}{mass}}$$

For example, if a 100 kg person absorbs 0.01 J of radiation energy:

$$D = \frac{0.01}{100} = 0.0001 \text{ Sv} = 0.1 \text{ mSv}$$

However, some radiation is more damaging than others. In order to assess how much damage the radiation does to the body, the absorbed dose is multiplied by the **quality factor (Q)** to provide a measurement called the **human dose equivalent (H)**. Like the absorbed dose, the human equivalent dose is measured in sieverts. The more damage that the radiation can do, the higher the quality factor and, so, the higher the human dose equivalent. The following table shows the quality factors of radiation.

Type of radiation	Quality factor
X-rays, gamma radiation, beta radiation	1
Neutrons (depending on energy)	2–20
High-energy protons, alpha radiation, heavy nuclei	20

$$\mathbf{H = Q \times D}$$

A 100 kg person who absorbs 0.1 mSv of energy from beta radiation will get a human equivalent dose of 0.1 mSv. However, if the energy came from alpha radiation, the human equivalent dose would be $20 \times 0.1 = 2$ mSv.

The table on the next page gives the typical H values for a number of different radioactive sources.

Human equivalent dose, H (mSv)	Source
0.005	1 hour in an aircraft on an international flight
0.06	one chest X-ray
0.7	one mammogram
1	living 1 year in a house with granite tile flooring
1.5	background radiation experienced by the average Australian in a year
2.4	world average background radiation in a year
2.5	total experienced by the average radiography technician in a year
2.6	one head CT scan

How much is too much?

The amount of radiation that a person can experience before they suffer damage to their health depends upon the size of the dose received as well as the length of time over which they received it. High radiation doses tend to kill body cells while low doses damage the structure of the DNA within the cell, leading to cancer and leukaemia. The reproductive cells are particularly at risk.

A radiographer prepares to X-ray a patient. Notice that the patient is wearing a protective gown. This gown is lined with lead to protect the rest of the patient's body from the X-rays. When the X-ray is ready to be taken, the radiographer and doctor will retreat behind a radiation shield in order to limit their own exposure to radiation.

In fact, high doses of radiation can kill so many cells that entire organs are destroyed. The higher the dose, the sooner the effects of radiation poisoning will appear and the higher the probability that the exposure will be fatal. **Acute radiation syndrome** is caused when a person is exposed to a high dose of radiation over a short period of time — minutes or hours. This can result in extreme nausea, diarrhoea, internal bleeding, bone marrow depletion and organ failure. The effects of acute radiation doses are shown in the table on the next page.

Most people will generally experience less than 0.1 Sv over the course of their life. Obviously, those who work with nuclear sources for a living such as radiographers, uranium miners and nuclear engineers would receive more than this. However, industry standards are applied to these occupations to minimise their risk to prolonged exposure effects. For example, people who work with radiation sources (radiographers, nuclear engineers, nuclear power plant workers) are limited to an exposure of 0.1 Sv over a 5-year period (0.02 Sv/year average) while uranium workers are not permitted to be exposed to more than 0.013 Sv in a year.

Radiation dose (Sv)	Effects
0.75	Causes vomiting in 10 per cent of people
1	Short-term effects such as nausea and diarrhoea. Development of cancer after many years in around 5 per cent of people.
3–5	Damage to bone marrow which results in infection and haemorrhage. Can lead to death in about 50 per cent of people within two months if medical treatment is not available.
> 10	Death within 10 days due to fluid and electrolyte imbalance, bone marrow and gastrointestinal damage and infection
> 40	Death within 48 hours due to damage to the vascular systems resulting in an accumulation of fluid in the brain

HOW ABOUT THAT!

French physicist Henri Becquerel accidentally discovered radioactivity while investigating the fluorescence of uranium salts in 1896. When he developed a photographic plate that had been in a drawer near his bench top, he found that it had been fogged up by radiation from the uranium salts.

This effect of radioactivity is now used in a protective device worn by people who work with radioactive materials. The 'fogging' of the film in this device measures the amount of radioactivity they have been exposed to.

Becquerel was the first scientist to report the effects of radioactivity on living tissue. He suffered from burns on his skin as a result of carrying a small quantity of the element radium in his pocket.

6.4.4 Radium Girls

In the 1920s, the United States Radium Corporation employed hundreds of women at their factory in Orange, New Jersey, to paint their trademark 'glow in the dark' paint onto the dials of watches. To paint the tiny numbers and indicator hands of the watches, the women would use fine-tipped brushes and they would often lick the tips of the brushes to keep the points of the brushes sharp. Many years later, these same women started to develop serious bone-related problems, particularly in the jaw. Many of the women died of cancer before the company revealed that the paint was made from a radium salt that was a million times more radioactive than uranium. Hundreds of these 'Radium Girls', as they were called in the newspapers of the day, died as a result of repeated exposure to the radiation.

The Radium Girls of the 1920s suffered radiation poisoning from the radium that they used to paint the dials of the first 'glow in the dark' watch faces.

6.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What type of nuclear radiation is described by the following statements:
   (a) a radioactive particle that has the same size and mass as an electron
   (b) a radioactive particle that is made up of two protons and two neutrons
   (c) the type of radiation that can penetrate the human body and can be stopped only by a thick shield of lead or concrete
   (d) a radioactive particle that can travel almost at the speed of light
   (e) a radioactive particle that carries the highest amount of charge
   (f) radiation which has the smallest penetrating power
   (g) radiation that travels as a wave rather than a particle.
2. Why are alpha, beta and gamma radiation referred to as ionising radiation?
3. What is background radiation caused by?
4. **Describe** factors that affect how much radiation you absorb from a radioactive source.
5. What electric charge is carried by an alpha particle?
6. How are we protected from cosmic radiation from outer space?

Think

7. Why does alpha radiation have a higher quality factor than gamma and beta radiation even though it is less penetrating?
8. During nuclear tests in the 1950s, US soldiers were told that they were safe from alpha radiation as long as they didn't open their mouths. Why do you think they were told this?
9. Radiographers perform hundreds of X-rays, CT scans and mammograms every week, yet their yearly radiation exposure from their job is only 2.5 mSv — just under the amount you would experience in a single head CT scan. How is this possible?
10. The crews of passenger jets are exposed to more radiation than most people. Where does this extra radiation come from?

Using data

11. A scientist wished to determine the type of radiation emitted by a radioisotope. She had three materials (paper, plastic and lead) and an instrument called a Geiger counter, which detects nuclear radiation. She covered the radioisotope with each of the three materials and measured the radiation that passed through each material. The results of her experiment are shown in the table at right. What type of nuclear radiation does this radioisotope emit? **Explain** your answer.

Results of radioactivity experiment

Material	Effect on Geiger counter readings
Paper	No effect on readings
Plastic	Readings fell by two-thirds
Lead	Large fall in readings

Investigate

12. Most of the background radiation we experience comes from a radioactive element called radon. Find out (a) where this radon comes from and (b) why people in countries where their houses have cellars are worried about radon.

6.5 Helpful radiation

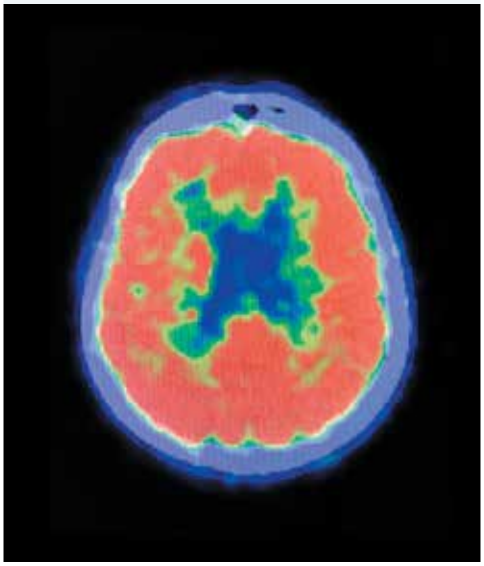
Science as a human endeavour

6.5.1 Medical uses of radiation

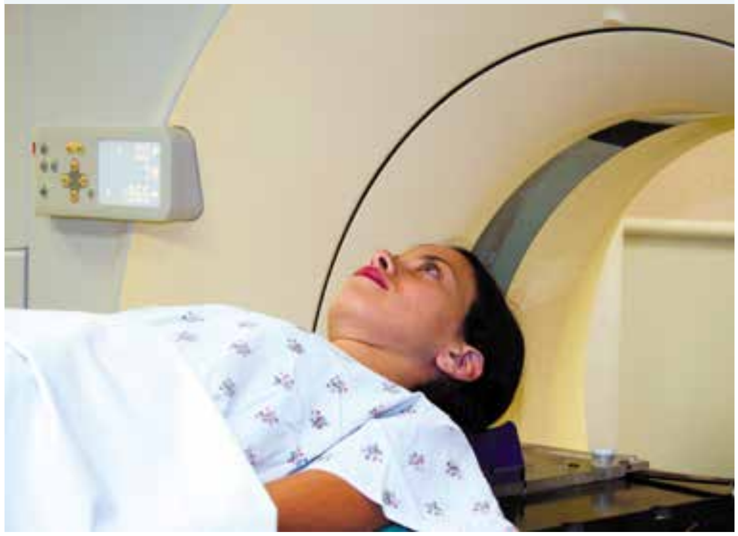
Diagnosing disease

Nuclear medicine imaging techniques use radioisotopes with short half-lives to find tumours, blockages in blood vessels and problems with the body's organs. The radioisotopes are given to the patient in the form of either an injection or as part of a thick liquid that the patient drinks. The type of radioisotope

A PET image of the human brain



Various radioisotopes can be used to treat and diagnose disease. Here a PET scan is being carried out on a patient.



used depends upon what tissues or organs are being investigated and the type of diagnostic tool being used. One of the most commonly used is **positron emission topography (PET)**. During a PET scan, the radioisotope absorbed by the tumour or tissue cells produces gamma rays. These pass through the patient's body and are detected by the scanner moving around the patient to form a 2-D image 'slice'. By moving the patient slowly through the scanner, hundreds of these slice images are taken and the slices are then reassembled by computer into a 3-D image of the tissue or tumour.

Some of the radioisotopes used in the treatment and diagnosis of disease

Radioisotope	Use	Half-life
Phosphorus-32	Treatment of leukaemia	14.3 days
Cobalt-60	Used in radiotherapy for treating cancer	5 years
Barium-137	Diagnosis of digestive illnesses	2.6 minutes
Iodine-123	Monitoring of thyroid and adrenal glands, and assessment of damage caused by strokes	13 hours
Iodine-131	Diagnosis and treatment of thyroid problems	8 days
Iron-59	Measurement of blood flow and volume	46 days
Thallium-201	Detection of damaged heart muscles	3 days

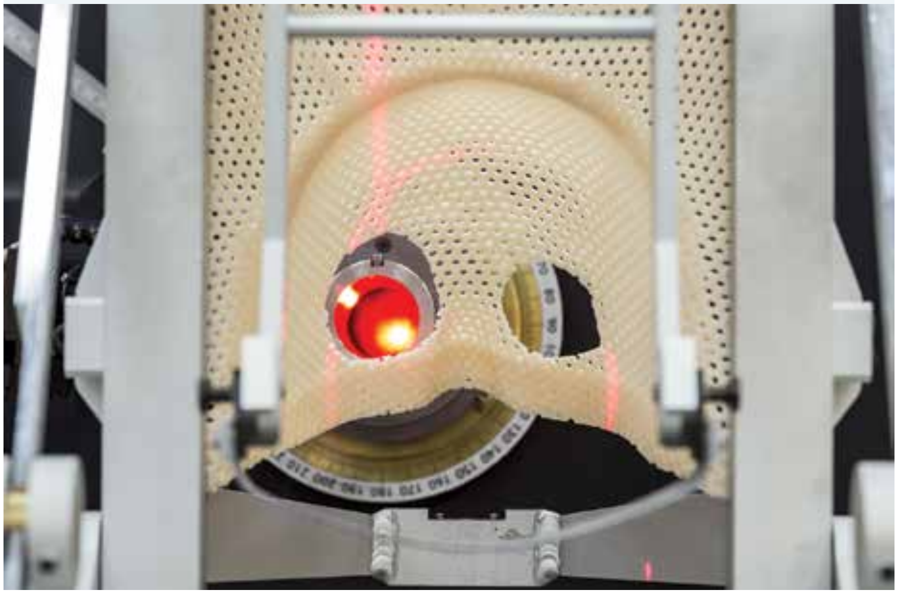
Radiotherapy

Radiotherapy is the use of radiation such as X-ray or the radiation produced by decaying isotopes to kill cancer cells or prevent them from spreading. It is often used along with other treatments such as surgery or chemotherapy. Unlike chemotherapy, radiotherapy can be targeted precisely so that damage to healthy tissue surrounding the cancer is minimised.

There are two main methods by which radiotherapy can be administered. In **external radiotherapy**, radiation is directed at the cancer by a machine which moves around the patient. Each beam sent by the machine strikes the tumour from a slightly different direction with the result that the tumour is blasted with large amounts of radiation while the healthy cells between the machine and the tumour receive much less radiation.

The other method, known as **internal radiotherapy** or **brachytherapy**, involves placing radioisotopes inside the body at or near the site of the cancer. In some cases both external and internal radiotherapy are used. The type of treatment depends on the type of cancer, its size and location, as well as the general health of the patient.

External radiotherapy

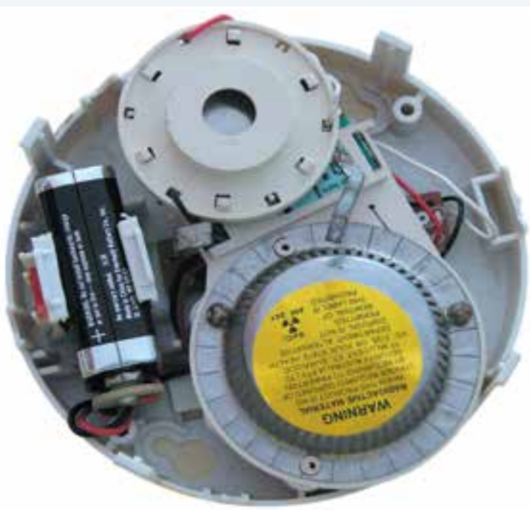


6.5.2 Smoke alarms

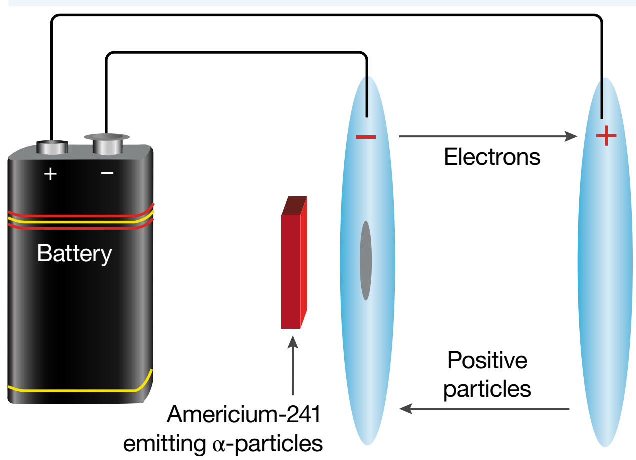
Inside an ionisation smoke alarm in the ionisation chamber are two plates that are oppositely charged. There is also a tiny amount of americium-241, which has a half-life of 432 years. Americium-241 atoms emit alpha radiation and change into neptunium-237 atoms. The alpha particles knock electrons off the nitrogen and oxygen molecules in the air. This creates positive particles and free electrons. The positive particles are attracted to the negative plate, and the electrons are attracted to the positive plate. A small current is set up.

When smoke particles are drawn into the smoke alarm, they attach themselves to the positive ions, make them neutral and disrupt the current. This change is sensed by the detector and the siren sounds.

Smoke alarms are cheap and save lives.



What happens in the ionisation chamber?



HOW ABOUT THAT!

No butts

Some smoke detectors can detect different types of smoke, including cigarette and cigar smoke. Different particle sizes absorb differing amounts of radiation. These smoke alarms are used in places where smoking is discouraged such as aeroplane toilets and non-smoking areas in restaurants. Some can even be programmed with a voice message warning smokers that it is about to sound the alarm!

6.5.3 X-rays — not just for medicine!

Today X-rays are used not only for medical purposes, but also to detect flawed welds in engineered structures, to study under-painting in famous art works like the Mona Lisa and even to observe distant objects beyond the edges of our galaxy.

This painting of a vase of flowers was credited to an anonymous artist. However, X-ray imaging of the canvas revealed a scene of two wrestlers painted beneath. This helped historians to identify this canvas as the work of Vincent Van Gogh.

Engineer studying an X-ray of an aircraft part. Aeroplanes undergo regular inspections to check for any defects that could cause parts, or the entire aircraft, to fail.

6.5.4 Irradiating food

Food irradiation is a commonly used process in which food is exposed to a source of ionising radiation, usually gamma rays from cobalt-60. It has a number of different purposes. It can be used to kill pests on fruit and vegetables instead of using chemical treatments. It is particularly important for controlling unwanted pests that can be imported along with the produce from other countries. Food irradiation is used by food processors to kill harmful bacteria such as salmonella and campylobacter that may be found in meat, poultry and eggs. These bacteria can cause serious illness if consumed.

Irradiation also helps to keep food from spoiling as quickly by destroying moulds and yeasts and by slowing the action of enzymes within the food.

However, food irradiation has a downside as the process also destroys some of the food's vitamins. While B vitamins such as riboflavin and niacin, and vitamin D are not particularly affected, levels of radiation sensitive vitamins A, B1 (thiamine), C, E and K can be reduced by as much as 20 per cent.

6.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What is radiotherapy?
2. How does external radiotherapy differ from internal radiotherapy?
3. **Explain** how a smoke alarm works.
4. **Describe** how a PET scan produces an image of the body.
5. Which isotopes are used in nuclear medicine for the diagnosis or treatment of (a) digestive problems (b) thyroid tumours (c) leukaemia?
6. **Explain** how radioisotopes used in food preservation stop food from spoiling.

Think

7. (a) Is iodine-131 a more stable radioisotope than barium-137? **Explain**.
   (b) The use of barium-137 in the diagnosis of digestive illnesses involves the patient drinking it in a syrup. What property of barium-137 makes its use quite safe?
8. Is cobalt-60, used in the treatment of cancer, more likely to be used in external radiotherapy or internal radiotherapy? Use the information in the table to **explain** your answer.
9. Why is it important that imaging is done within a short period of time after the patient has been given the appropriate radioactive isotope?
10. Why do the radioisotopes used for diagnosis not cause radiation sickness in the patient?

Investigate

11. Find out what the following isotopes are used for: (a) cadmium-109 (b) californium-252 (c) krypton-85 (d) copper-67 (e) radium 226 (f) uranium-234.
12. Radiotherapy is an effective method of treating cancer. However, it has a number of side effects. Research what the side effects are.

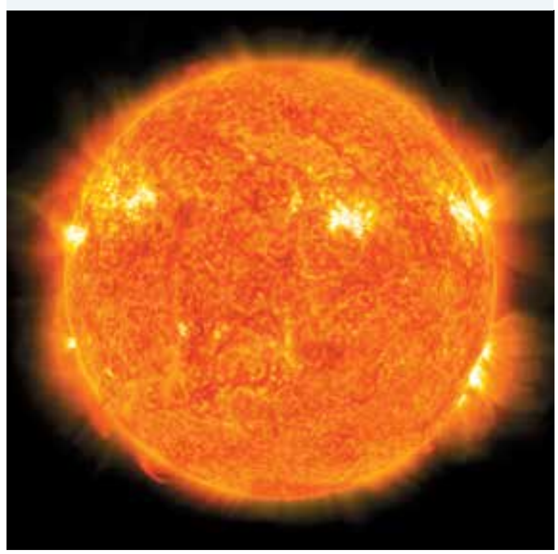
6.6 Energy from the atom

6.6.1 Nuclear reactions

The sun is a powerhouse of energy. It provides radiation in many different forms; not just as gamma and cosmic rays, but also as light and heat that allows life on Earth to flourish. All of this energy comes from special types of reactions that are occurring deep within the sun's core. While we will look at plenty of chemical reactions which involve the electrons in the outside of atoms in a later topic, for now we will look at reactions that involve the nuclei of atoms. These are called, unsurprisingly, nuclear reactions and they occur only under certain conditions. By harnessing the power of these reactions, we can produce vast amounts of energy.

When one substance reacts with another in a chemical reaction, bonds involving their electrons are broken and formed between the atoms of the substances to form new chemical products. In these reactions, the atoms present in the reacting substances are the same ones that are present in the products of the reaction.

The largest nuclear reactor near us is the sun. Every second, 500 million tons of hydrogen is fused into larger elements producing energy, including light and heat.



Nuclear reactions are those that take place when the nucleus of an atom interacts with either another nucleus or a nucleus particle. As a result of these reactions, new atoms are formed and energy is released. The two most important types of nuclear reaction that provide energy are nuclear fission and nuclear fusion.

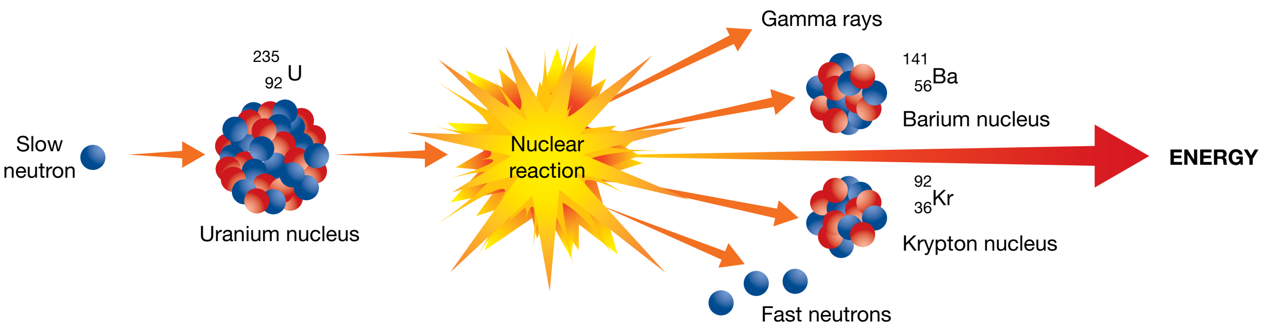
6.6.2 Nuclear fission

Nuclear fission occurs when the nuclei of large atoms such as uranium or plutonium split to form the nuclei of smaller atoms, releasing energy in the form of radiation and heat. In some nuclear reactors, the fission of uranium-235 is caused when a neutron is absorbed by the nucleus. The nucleus splits to form two smaller nuclei (which are called **fission products**) as well as releasing more neutrons, gamma rays and heat energy.

If the neutrons released in this process then go on to cause the splitting of other uranium-235 nuclei, a **chain reaction** occurs. The rate at which energy is produced can be controlled by limiting the number of neutrons that can react with other uranium nuclei. This is what happens in a nuclear reactor. The destructive power of nuclear weapons, on the other hand, is caused by an uncontrolled chain reaction.

An example of a nuclear fission reaction

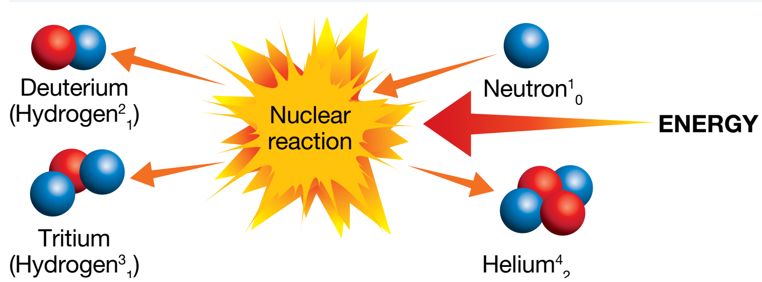
Nuclear equation: $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$



6.6.3 Nuclear fusion

In **nuclear fusion**, two small nuclei combine to form larger nuclei releasing energy. In the sun, the nuclei of the hydrogen isotopes deuterium (hydrogen-2) and tritium (hydrogen-3) fuse together to form helium nuclei, releasing neutrons and massive amounts of heat and radiation. Nuclear fusion has so far been reliably produced only at very high temperatures of millions of degrees. However, the quest to perfect fusion at low temperatures — called **cold fusion** — continues. If cold fusion were to be achieved, huge amounts of energy could be produced from just the hydrogen in water!

An example of a nuclear fusion reaction

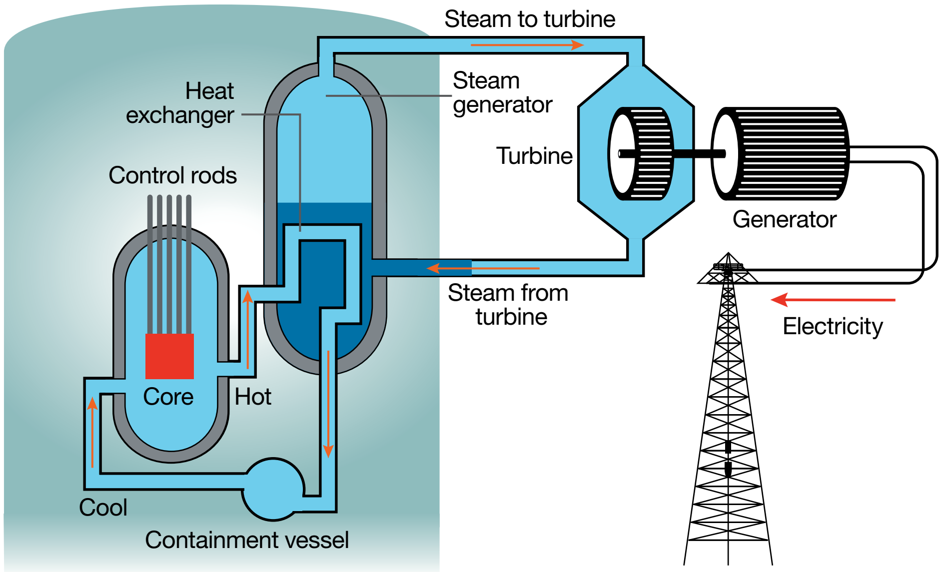


6.6.4 Nuclear power stations

Nuclear energy is used for electricity generation in some countries, for up to 75 per cent of their energy needs. Nuclear fuels produce radiation; however, this is not electricity. So, how do these power stations produce power?

The fuel for a nuclear power station is natural uranium, slightly enriched with uranium-235. This is because, besides decaying, uranium-235 will spontaneously split (fission) if hit by a neutron, starting a chain reaction. The **control rods** are used to slow or increase the rate of the reaction by absorbing spare neutrons. They are lowered or raised as needed.

A nuclear power station



When uranium-235 splits, an incredible amount of energy is produced as heat and gamma radiation. One gram of uranium produces a million and a half times more energy than the burning of one gram of methane. This amount of **thermal energy** heats water that turns into steam and is then channelled through pipes out of the containment vessel. This steam is used to spin a turbine that is connected to an electrical generator, turning the kinetic energy of the moving steam into electrical energy. This is the same process of using steam to generate electricity in coal- or gas-fired power stations.

6.6.5 The nuclear energy issue

At present, Australia has only one nuclear reactor and it is used for research purposes and to produce radioisotopes for medical and industrial purposes. While many countries use nuclear energy to provide their electricity, Australia has yet to do so. It is not an easy decision to make and there are many arguments in favour of and against the use of nuclear energy.

6.6.6 The arguments for nuclear energy

Ready access to fuel

As Australia has 30 per cent of the world's uranium supply, we are able to supply our own nuclear fuel for any reactors built here. Presently, we export nearly all of the 7000 tonnes of uranium ore that comes from mines in the Northern Territory (Ranger and Nabarlek) and South Australia (Roxby Downs).

No greenhouse gases

Coal-fired power stations pump enormous amounts of greenhouse gases into the Earth's atmosphere, gases which are believed to contribute to global warming, acid rain and climate instability. The average coal-fired power station produces about seven million tonnes of carbon dioxide each year, as well as around 200 000 tonnes of sulfur dioxide (a major source of atmospheric pollution) and about the same amount again of other waste products that contain toxic metals such as arsenic, cadmium and mercury. Nuclear power stations, on the other hand, release only water vapour into the air.

Efficiency

One of nuclear power's biggest advantages is that it is extremely efficient in terms of the amount of energy that you get from a small amount of uranium fuel. One tonne of uranium produces more energy than is produced by several million tonnes of coal or several million barrels of oil. The table at right shows the typical heat values of various fuels.

Fuel source	Energy produced from 1 kg of fuel (MJ)
Brown coal	9.7
Firewood	16
Black coal	30
Natural gas	39
Crude oil	46
Uranium (light water reactor)	500 000

Note: 1 MJ = 1 million joules

6.6.7 The arguments against nuclear energy

Cost

While nuclear fuel and its efficiency make it more competitively priced than fossil fuels, the costs of building a nuclear reactor are much higher than those involved in coal-burning power stations, especially as the safety measures that must be incorporated into their design make them more expensive.

Safety concerns

Undoubtedly, the biggest concern of most people is with regard to the safety of nuclear reactors. This concern is difficult to dismiss in light of the widely reported mishaps at Three Mile Island in 1979, Chernobyl in 1986 and Fukushima in 2011. The Chernobyl and Fukushima nuclear disasters are described in subtopic 6.7.

Accidents at nuclear facilities releasing deadly radiation into the atmosphere or water can affect whole regions. The background radiation levels in Europe, Africa and Asia were all increased by the radiation released from Chernobyl. Technical and operator faults were responsible for the Three Mile Island and Chernobyl incidents, while the Fukushima disaster was initiated by an earthquake and a tsunami. Other potential threats to the safe operation of nuclear reactors include terrorism, sabotage or even cyberattack.

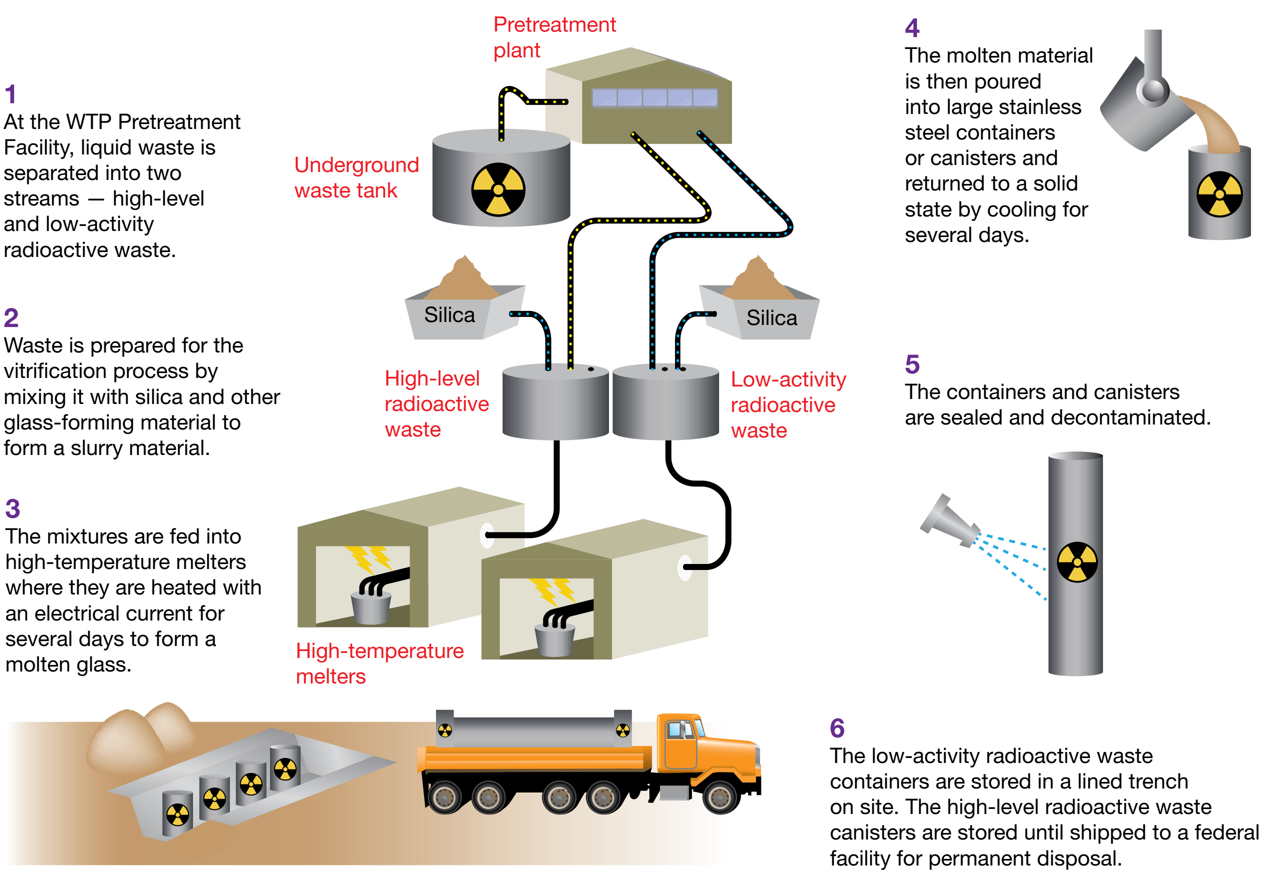
The hazards of uranium

Radioactive material makes its way into air, water, soil, food, animals and human tissue. Uranium releases radioactive radon gas into the atmosphere when it is mined and milled. This radioactive gas returns to Earth as rain, contaminating soil and water. The solid radioactive wastes from mining, called **tailings**, can infiltrate through the soil and into the ground water or are dispersed into the environment by wind.

Nuclear waste management

The average nuclear reactor produces around 25 tonnes or so of spent fuel each year it is in operation. This waste is highly radioactive and gives off a great deal of heat. While most of this waste can be reprocessed for reuse, it must be stored until this can be done. Many methods of storing or disposing of this waste have been used including storage in steel or concrete containers that are then buried in deep disused mineshafts or in isolated areas, and **vitrification**, where liquid radioactive waste is mixed with glass and poured into steel drums. The steel drums are then dug deep into the ground or under the sea floor. However, none of these has yet proved satisfactory due to the risk of leakage and subsequent damage to the environment.

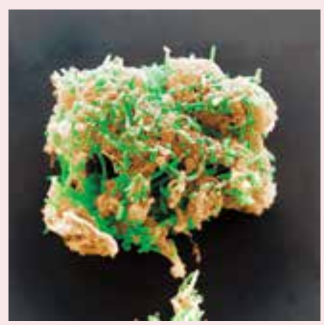
Vitrification process



HOW ABOUT THAT!

Yummy — nuclear waste!

The strange green things in this photo are *Geobacter metallireducens*, a species of anaerobic bacteria that use metals to produce energy in the same way that humans use oxygen. These bacteria are hardy enough to survive in radioactive environments and they are able to convert soluble uranium waste, which can leach out of storage containers and contaminate water supplies, into a solid form which is easier to dispose of safely. Other helpful species of *Geobacter* being studied can remove petroleum contamination from polluted water and convert waste organic matter to electricity.



6.6 Exercise: Remember and think

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Remember

1. Write down two advantages and two disadvantages of nuclear power stations.
2. **Explain** the difference between nuclear fission and nuclear fusion.
3. What type of reaction is happening in the sun?
4. How are nuclear reactions different from chemical reactions?
5. **Explain** briefly how a nuclear power station generates electricity.

6. **Describe** the nature of nuclear waste.
7. **Explain** how radioactive waste can affect people via its effect on the environment.
8. **Describe** some technological solutions to the disposal of nuclear wastes.

Think

9. Some people have suggested sending all of the nuclear waste into the sun by rocket to get rid of it. Is this a good idea? **Explain** your answer.
10. Nuclear submarines have two big advantages over conventional diesel submarines. What are they?

Investigate

11. Research the following types of nuclear reactors and find out: (a) what they are built from (b) what fuel rods and control rods are (c) what type of nuclear reaction occurs in the reactor (d) how the reactor is kept cool (e) how electricity is generated (f) what kinds of safety features are used.
    (i) RBMK
    (ii) PWR
    (iii) GCR
    (iv) FBR

Create

12. Imagine that you have been asked to design a series of signs to be placed around a nuclear waste site somewhere in the desert warning of its danger. However, you've been asked to do this in the form of a picture rather than using words on the basis that the nature of the hazard needs to be understood by anyone — including those who can't read or who have no idea what nuclear waste is! Design a sign that fulfils these criteria.

learnon Resources — ONLINE ONLY

Watch this eLesson: Australia's nuclear future (eles-1075)

Complete this digital doc: Worksheet 6.1: The sun and nuclear fusion (doc-12770)

6.7 The dark side of radiation

While nuclear technologies such as radiotherapy and generation of electricity are beneficial to society as a whole, there is no doubt that nuclear technology is very much a two-edged sword as Chernobyl, Fukushima, Hiroshima and Nagasaki remind us.

6.7.1 When reactors go wrong

Like any other piece of complex technology, a nuclear reactor can work safely only if its many individual systems are functioning smoothly and efficiently. They must be well-maintained and well-managed by highly trained personnel. Unfortunately, in many cases the flaws of a nuclear reactor's design are not spotted until it is too late.

6.7.2 Chernobyl 1986

Reactor 4 was an old design that used graphite moderators, used water as a coolant and had no radiation containment shields around the reactor cores. On 25 April 1986, Reactor 4 at Chernobyl was scheduled to be shut down for routine maintenance. Due to a series of operational errors, nearly all of the control rods were withdrawn from the core to compensate for a power loss. This caused the reactor to become rapidly unstable and fission started to occur too quickly. While an attempt was made to fully insert all of the control rods (absorbing all of the neutrons in the core and stopping the fission reaction), a reaction with the graphite tips of the control rods suddenly caused an uncontrollable power surge in the reactor. In 4 seconds, the power rocketed up to 100 times its normal value and the reactor core reached 5000 °C (about the same temperature as the surface of the sun), causing some of the fuel rods to rupture. The hot fuel particles hit the cooler water and caused a steam explosion that destroyed the reactor core. The graphite core caught fire and, because it had no containment shield, some of the vaporised radioactive fuel went into the atmosphere.

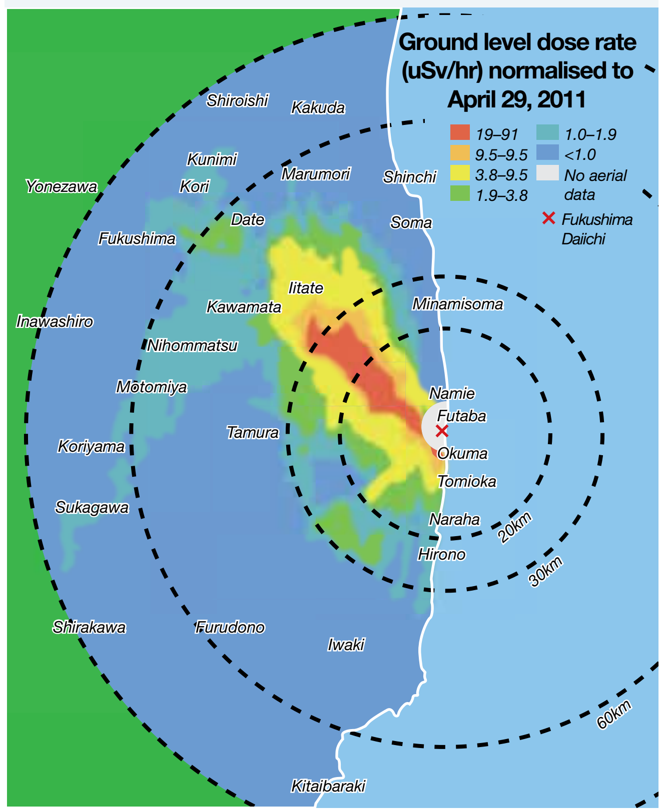
While only two people were killed in the original explosion, three others died during the night and fifty emergency workers died from acute radiation poisoning. Since the accident, the rate of thyroid cancer in children has been ten times higher in the region around Chernobyl and, of the 600 000 people contaminated by radiation, 4000 have died from long-term cancers.

The remains of Reactor 4 after the explosion

6.7.3 Fukushima 2011

The Fukushima Daiichi nuclear disaster was caused by a series of unlucky events occurring one after another. On 11 March 2011 a massive earthquake occurred off the coast of Honshu (the main island of Japan) leaving the Fukushima nuclear reactor complex relatively unharmed but reliant on its back-up generators. Unfortunately, the earthquake caused a tsunami that struck the coast of Honshu less than an hour later, killing more than 19 000 people and destroying over 1 000 000 buildings. The reactors at Fukushima Daiichi were flooded by the 15 m high tsunami, disabling 12 of the 13 back-up generators as well as the heat exchangers that released waste heat into the sea. Without power, the circulation of water coolant around the reactor cores ceased, causing them to become so hot that much of the coolant water was boiled off. The heat became high enough to melt the fuel rods in reactors 1, 2 and 3 (this is referred to as a **meltdown**). A reaction between the cladding of the melted fuel rods and the remaining coolant water produced hydrogen gas that exploded when mixed with the air. This threw nuclear material up into the atmosphere. More than 160 000 people had to be evacuated from the area for fear of radiation. While three employees at the Daiichi plants were killed directly by the earthquake and tsunami, there were no fatalities from the nuclear accident.

Map showing the amount of radiation absorbed per hour at ground level around Fukushima six weeks after the melt-down



6.7.4 Nuclear weapons

There are at least 30 000 nuclear weapons in the world today, enough to obliterate life from the face of the planet.

Fission bombs

As you'll recall from subtopic 6.6, a chain reaction occurs when slow neutrons strike a uranium-235 nucleus, causing it to break into smaller nuclei, releasing energy, radiation and more neutrons which, in turn, strike more uranium nuclei and so on. Nuclear reactors utilise a controlled chain reaction where the number of neutrons available to fission the uranium nuclei is manipulated to ensure that energy is released at a steady rate. Fission bombs (also called **atom bombs** or **A bombs**), on the other hand, rely on uncontrolled chain reactions in unstable radioactive materials. In an **uncontrolled chain reaction**, *all* of the released neutrons cause further reactions, releasing devastating amounts of energy (mainly in the form of heat and light) and radiation.

An uncontrolled chain reaction can occur only if the amount of radioactive material is over a certain mass — this is called the **critical mass**. The more fissionable the material, the smaller the critical mass will be. For example, the critical mass of enriched uranium ore in which 97 per cent of the uranium atoms are fissionable uranium-235 is about 15 kg. Uranium that is 15 per cent uranium-235 has a critical mass of 400 kg.

If you wanted to cause an uncontrolled chain reaction in naturally occurring uranium ore (which is made up of less than 1% of uranium-235) you would need more uranium than there is in the whole world!

Structure of a fission bomb

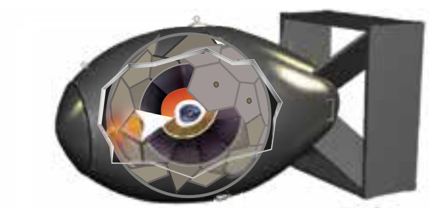
Fission bombs use lumps of fissionable material such as uranium or plutonium. Each lump is smaller than the critical mass. The fission bomb works by bringing two or three of these subcritical masses together, usually using an explosive charge. When the masses are combined, the mass exceeds the critical mass, causing a nuclear explosion.

Fusion bombs

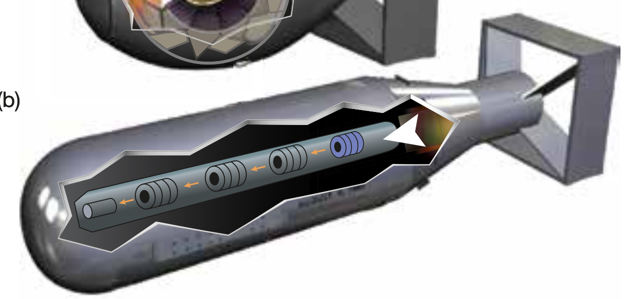
Fusion bombs (also known as **hydrogen bombs** or **H bombs**) detonate in two stages. The first stage involves the explosion of a small fission bomb that creates the necessary high temperatures and the second stage occurs when the superheated hydrogen nuclei combine.

(a) This implosion bomb uses plutonium-239 as its energy source. It is similar to the bomb code-named Fat Man that was dropped on Nagasaki on 9 August 1945.
(b) This gun-style bomb uses enriched uranium-235 and is similar to the bomb code-named Little Boy that was dropped on Hiroshima on 6 August 1945.

(a)



(b)



INVESTIGATION 6.2

Modelling critical mass

AIM: To model how nuclear reactions can become critical

You will need:

40 marbles
a metre ruler
chalk

- Draw up a data table like the one shown at right.
- Find a flat area where you can draw a chalk circle (outside on concrete is a good idea). Be careful that no-one slips on escaped marbles!
- Use the metre ruler and the chalk to draw a circle on the ground. The circle should have a radius of about 50 cm.

Circle radius (cm)	Number of collisions
50	
40	
30	
20	
10	

- Place 39 of the marbles evenly throughout the area of the circle.
- Place a single marble just outside the edge of the circle and shoot it into the marbles in the circle. Count the total number of marbles that were involved in one or more collisions. Enter this value into your data table.
- Repeat this procedure for circles that have radii of 40 cm, 30 cm, 20 cm and 10 cm.

Discussion

1. What circle radius gave the most collisions?
2. What relationship did you find between the circle radius and the number of marble collisions?
3. Each circle had the same number of marbles spread evenly over its area. In which circle were the marbles most densely packed (closest together)?
4. The total circle area represents the amount of uranium in a sample, while the areas covered by each marble represent the uranium-235 in the sample. In which circle did the marbles cover the biggest fraction of the total area? (This represents the richness of the sample.)
5. Each marble collision represents the fission of one of the uranium-235 nuclei. How did the richness of the sample circles affect the number of fission reactions/collisions?
6. Is it more likely for chain reactions to occur in samples with a high richness or a low richness? Explain.

6.7.5 Effects of nuclear weapons

When nuclear weapons are detonated, enormous amounts of heat and radiation spread out from the centre of the blast (known as **ground zero**) in what is called a **thermal flash**. This radiation forms a fireball which generates the distinctive mushroom cloud associated with nuclear weapons. The fireball from the Hiroshima bomb formed a fireball 7 km across. At locations close to ground zero, most substances were melted or burned and organic matter (including people) was vaporised. People up to 50 km away received serious burns and those who looked directly at the flash were blinded.

Radiation burns on the back and arm of a victim of the Nagasaki nuclear explosion. Darker areas of clothing produced more heat and led to burning of the skin in the shape of the fabric pattern.

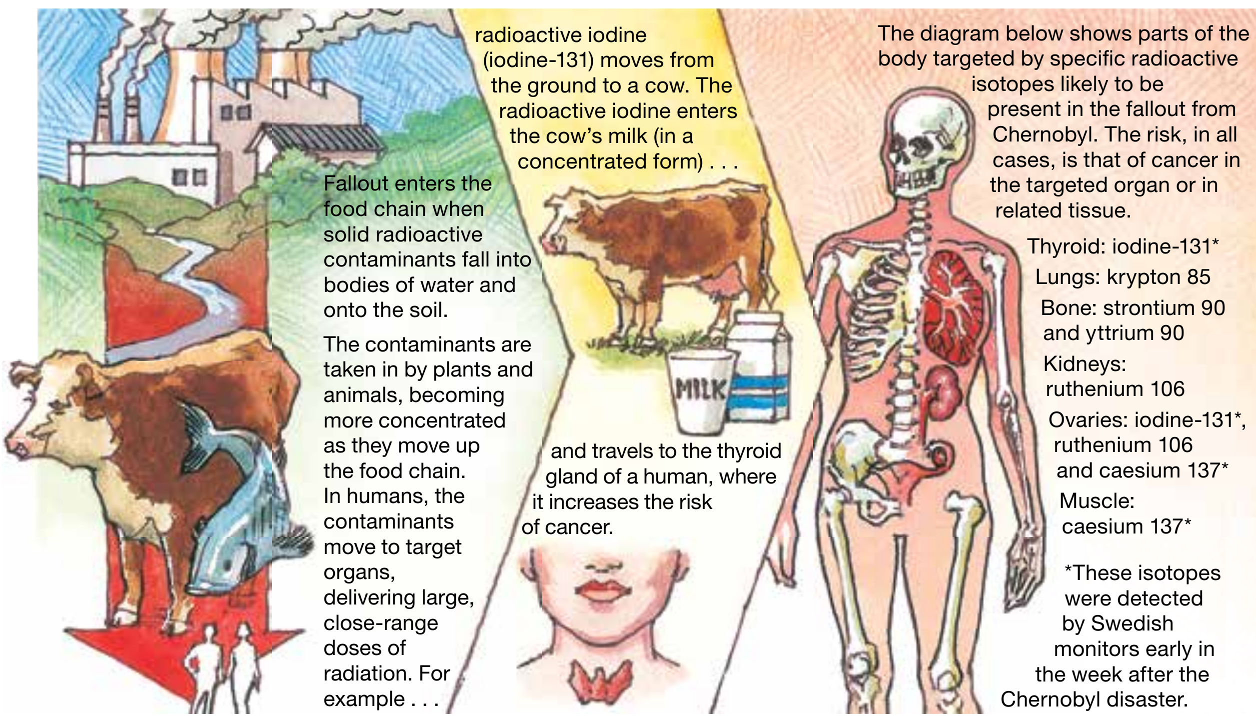
After the initial blast, the vaporisation of particles close to the blast causes an implosion of air from further out. When these inrushing air particles collide, they cause a high pressure shock wave to spread outwards at speeds of up to 3000 km/h. This shock wave causes the destruction of buildings, blowing them outwards from the centre of the blast.

The detonation of nuclear devices releases large amounts of radiation in the form of gamma rays which cause very strong electromagnetic fields to form and then collapse. These electromagnetic fields can burn out electrical and electronic systems including computer networks and power grids, and even disrupt the electrical systems that control cars, planes and weaponry. This burst of electromagnetic activity is called an **electromagnetic pulse**.

The most devastating effects for survivors are due to radiation exposure. As we saw earlier in this topic, large amounts of radiation, as would be experienced by those closest to the blast, would be fatal with the level of exposure reducing with increasing distance from ground zero. The DNA in a survivor's cells can be damaged, leading to cancer, leukaemia and immune system collapse later in life, while damaged DNA in the sex cells means that their children and even grandchildren may suffer mental or physical defects.

Atomic bomb destruction, Hiroshima, Japan. Around 90 per cent of the buildings were destroyed, with only a few concrete-reinforced buildings surviving. Some 70 000 people died instantly, with tens of thousands more dying in the aftermath.

The radioactive nuclei formed during the nuclear reactions as well as tonnes of irradiated dust are blasted high into the atmosphere during detonation and the formation of the mushroom cloud. In the weeks following the nuclear explosion, these come back down to Earth as **nuclear fallout**. This radioactive fallout increases the background radiation for many years where it comes down, so people in the fallout zones are exposed to higher radiation levels with damaging effects.



6.7 Exercise: Remember and think

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Remember

1. What nuclear reaction is used in nuclear power stations?
2. **Describe** radioactive fallout.
3. **Explain** how the Chernobyl nuclear accident occurred.
4. **Define** the following terms: (a) melt-down (b) critical mass (c) electromagnetic pulse (d) ground zero
5. **Describe** the short-term and long-term effects of an atomic explosion.

Think

6. Why did the incidence of leukaemia increase among young children rather than adults after Chernobyl?
7. After the Fukushima disaster, people who may have been in the area may have been exposed to radioactive iodine. Why would these people have a higher chance of developing thyroid cancer?
8. **Explain** why nuclear energy is described by some as ‘a blessing and a curse’.
9. Why don’t the uranium deposits in the Earth’s crust undergo a chain reaction?
10. Is it possible for nuclear reactors to explode like atomic bombs? **Explain**.
11. One of the problems that led to the disaster at the Chernobyl nuclear reactor was due to the fact that the control rods could not be inserted into the reactor. Why would this have been a problem?

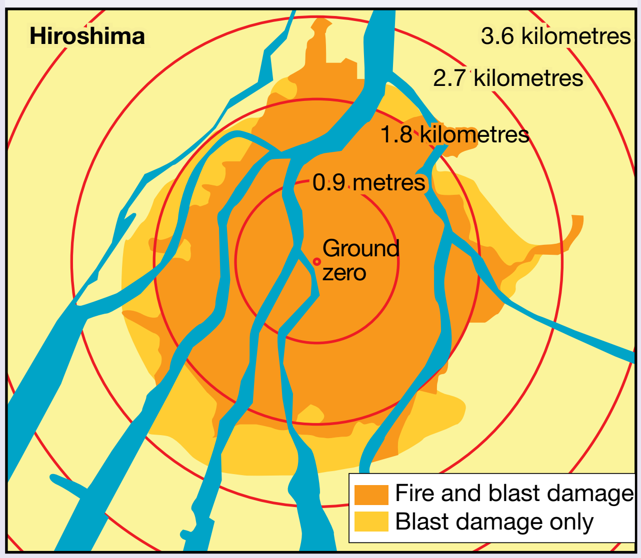
Investigate

12. Find out how a Geiger counter is able to measure the amount of radiation in a location.
13. Create a report on the accident at Chernobyl, Fukushima or Three Mile Island, explaining
    (a) how the accident affected the workers at the power plant and the surrounding towns and villages
    (b) the attempts made to reduce or control the damage caused by the radiation
    (c) the long-term effects of the accident.
14. Suppose you have been asked to write a report to discuss the following proposal: The use of radioactive elements should be banned in Australia. Give both sides of the argument, but present a conclusion for or against the proposal. You should also search the internet using keywords such as uranium, radiation, mining, nuclear and waste to find other useful sites.

Using data

15. The map and table shown at right indicate the distribution of deaths and injuries caused by the Hiroshima bombing.
    (a) Use this information to determine:
        (i) original population of Hiroshima before the bombing
        (ii) number of people killed who were within 1 km of ground zero.
    (b) As you would expect, the number of people killed gets smaller the further from ground zero that they were located. What explanations can you give that the percentage wounded doesn’t follow the same pattern?

Atomic bomb damage of Hiroshima



Distance from ground zero (km)	Killed	Injured	Population
0–1.0	26 700 (86%)	3 000 (10%)	31 200
1.0–2.5	39 600 (27%)	53 000 (37%)	114 800
2.5–5.0	1 700 (86%)	20 000 (25%)	80 300
Total	68 000 (27%)	76 000 (30%)	256 300

6.8 Review

6.8.1 History of radioactivity

- **investigate** the contribution of scientists such as Henri Becquerel, Marie and Pierre Curie, and Lord Rutherford to the development of the model of the structure of the atom and radioactivity **6.2**
- **describe** the impact of the discovery of radioactivity and the subsequent development of nuclear technology on the course of history **6.2, 6.5**
- **explain** how radioisotopes are used in nuclear reactors, radiometric dating, the treatment of cancer, medical diagnosis and food preservation **6.3**
- **examine** the risks associated with radioactivity **6.7**

6.8.2 Radioisotopes

- associate different isotopes of elements with the number of neutrons in the nucleus **6.3**
- **explain** why, in terms of the stability of the nucleus, some isotopes are radioactive while others are not **6.3**
- represent isotopes correctly in both symbols and words **6.3**

6.8.3 Nuclear radiation

- **describe** the characteristics of alpha, beta and gamma radiation, including penetrating power **6.4**
- **identify** the main sources of background radiation **6.4**
- **define** the half-life of radioisotopes **6.4**
- **explain** how the known half-life of some radioisotopes can be used to determine the age of rocks, fossils and ancient artefacts **6.5**
- **describe** the effects of radiation on survivors of Hiroshima and Nagasaki **6.4**

6.8.4 Energy from atoms

- **describe** the use of nuclear fission reactions in nuclear reactors **6.6**
- **explain** why not all radioactive elements are suitable for use in nuclear reactors **6.6**
- **describe** the events that led to the accidents at Chernobyl and Fukushima **6.7**
- **compare** and contrast fission and fusion reactions **6.7**
- **explain** how nuclear reactions differ from chemical reactions **6.7**
- **identify** the two methods used to create a critical mass in nuclear weapons. **6.7**

Individual pathways

ACTIVITY 6.1	ACTIVITY 6.2	ACTIVITY 6.3
Revising radioactivity	Investigating radioactivity	Investigating radioactivity further
doc-10651	doc-10652	doc-10653

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online only

FOCUS ACTIVITY

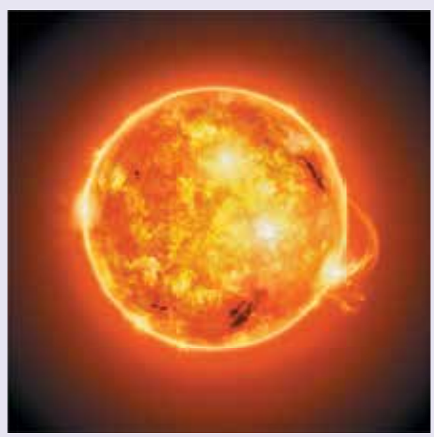
Explain why nuclear energy is described by some as ‘a blessing and a curse’.
Access more details about focus activities for this topic in the Resources tab (doc-10650).

assess**on**

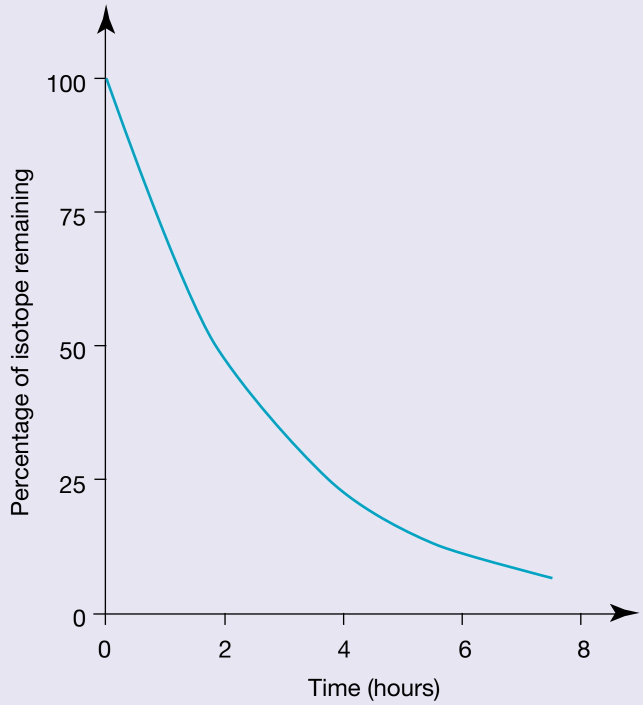
6.8 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers mayvary slightly.

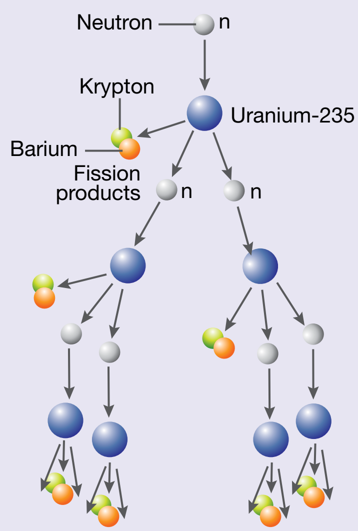
1. What do the following terms mean: enrichment, radiation, chain reaction?
2. **Explain** the function of each of these components of a nuclear reactor:
   (a) coolant
   (b) control rods
   (c) moderator.
3. Why is graphite rarely used as a moderator material in Western countries?
4. Uranium-235 has an atomic mass of 235 and an atomic number of 92.
   (a) How many protons
   (b) neutrons
   (c) nucleons does it have?
   (d) Why is uranium-235 more fissionable than uranium-238?
5. **Describe** the three main types of radiation and their penetrating power.
6. How do control rods allow the fission rate in a reactor to be manipulated?
7. **Explain** why a 2 kg lump of uranium-235 could not be made to explode like an atom bomb.
8. Determine how many X-rays you would need to have in a short period of time before you developed any acute symptoms of radiation poisoning.
9. It has been found that crews of international passenger jets develop cancers at a slightly higher rate than people in many other professions. Why do you think this is the case?
10. How does a controlled chain reaction differ from an uncontrolled chain reaction?
11. Imagine that it has been decided that a nuclear power station will be built in Queensland. Suggest possible locations for the site as well as a place to store the waste and justify your choices.
12. It has been suggested that a good way to dispose of nuclear waste would be to load it onto a rocket and send it into the sun. Do you think that this would work? **Explain** your answer.
13. The hydrogen atom exists as three different isotopes.
    (a) How are the atoms of each isotope different from the others?
    (b) **Identify** two features of the hydrogen atom that are the same for each of the three isotopes.
14. Alpha particles are helium nuclei containing two protons and two neutrons.
    (a) What is the electric charge of an alpha particle?
    (b) How does the mass and size of an alpha particle compare with the mass and size of a beta particle?
    (c) Suggest why alpha particles are easily stopped by human skin while beta particles are not.
    (d) Which type of radiation from the nucleus is more penetrating than either alpha or beta particles?
15. Why is radiation therapy able to be used in the treatment of cancerous tumours when radiation is able to *cause* cancer?
16. Which type of nuclear radiation travels at the speed of light?
17. Where does most of the natural background radiation that we experience every day come from?
18. Radioisotopes have many uses.
    (a) What property of radioisotopes makes them useful?
    (b) **Describe** some of the beneficial uses of radioisotopes.
    (c) Some radioisotopes are considered highly dangerous even after thousands of years. Why?
19. Two isotopes of the element carbon found naturally on Earth are carbon-12 and carbon-14.
    (a) How is every atom of carbon-14 different from every atom of carbon-12?
    (b) What features and properties do carbon-14 and carbon-12 have in common?
    (c) Which of the two carbon isotopes is stable?



20. The half-life of strontium-90 is 28 years. If a 400 g sample of strontium-90 was left to decay, how many grams of the sample would be left after:
    (a) 28 years
    (b) 56 years
    (c) 84 years?
21. Estimate the half-life of the isotope whose decay is shown in the graph at right.



22. **Explain** how it is possible to use carbon-14 to determine the age of a dead plant found embedded in rock.
23. How did the Curies know that there was an unknown element apart from uranium in pitchblende?
24. The total number of protons and neutrons in the nucleus is known as the ___________ number.
25. Tritium is an isotope of ___________.
26. Nuclear power stations produce energy from the ___________ of uranium-238.
27. Smoke alarms contain a radioactive isotope that produces ___________ particles.
28. Of the three main types of radiation, ___________ radiation is the most dangerous.
29. Americium-241 has a ___________ of 432 years.
30. How many protons and neutrons does hydrogen-3, ${}^{3}_{1}\mathrm{H}$ have?
31. What is the mass number of ${}^{12}_{6}\mathrm{C}$?
32. **Explain** what is happening in the diagram at right.



Test yourself

1. The half-life of an isotope is the
   (A) mass of the isotope that will decay over a year.
   (B) time taken for an isotope to cease being radioactive.
   (C) period taken for half of its particles to decay.
   (D) half the mass of an isotope in kilograms. **(1 mark)**
2. Which of the following isotopes is used in the diagnosis of thyroid tumours?
   (A) Cobalt-60
   (B) Iodine-131
   (C) Barium-137
   (D) Thallium-201 **(1 mark)**
3. Which of the following could be dated using Carbon-14?
   (A) stone axe head
   (B) dinosaur bone
   (C) medieval manuscript
   (D) early 20th century teacup **(1 mark)**
4. What is the purpose of the control rods in a nuclear reactor?
   (A) To store used nuclear fuel.
   (B) To absorb neutrons.
   (C) To keep the core cool.
   (D) To deflect neutrons back into the core. **(1 mark)**

5. Which of these isotopes is stable?
   (A) Carbon-12
   (B) Nitrogen-13
   (C) Hydrogen-3
   (D) Uranium-235 **(1 mark)**

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Complete this digital doc: Worksheet 6.2: Radioactivity: puzzles (doc-12771)

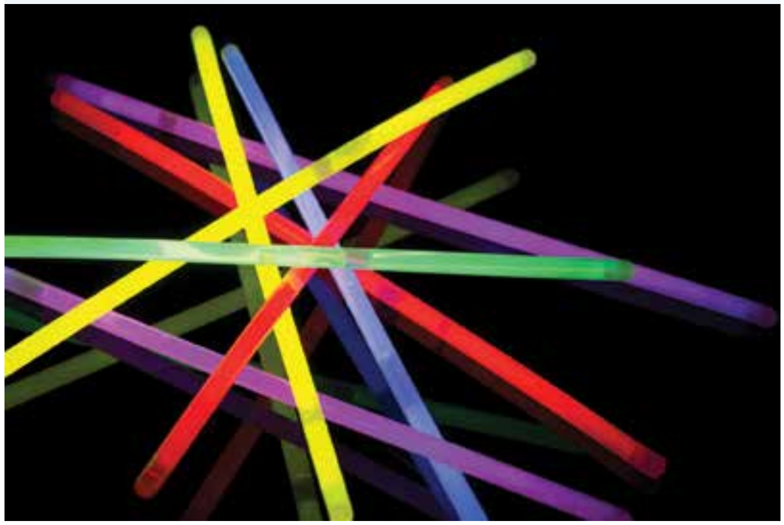
Complete this digital doc: Worksheet 6.3: Radioactivity: summary (doc-12772)

TOPIC 7
Chemical reactions

7.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

A glow stick produces light as a result of a chemical reaction between the substances inside the stick and its interior capsule. The energy released in the reaction causes the coloured fluorescent dye to glow.



7.1.1 Why learn this?

Did you realise that your life is full of chemical reactions? Useful materials such as cloth, paper, ink, ceramics, metals and polymers are all products of chemical reactions. Chemical reactions occur in the cooking and digestion of your food, and they must occur in all the cells of your body to sustain life. Medicines help cure illness by affecting the chemical reactions in your body. Even everyday occurrences — the rusting of an old car, the burning fire of the barbeque and the fizzing of a bath bomb — are the result of chemical compounds interacting.

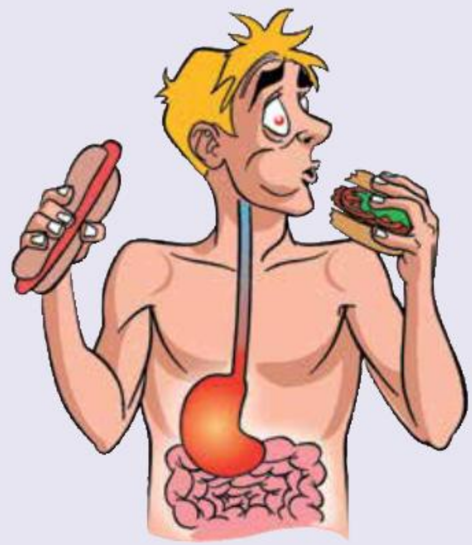
LEARNING SEQUENCE

The chemistry of eating

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Preparing, eating and digesting food all involve chemical reactions, many of which you already know about. Answer the following questions to find out what you already know about these important chemical reactions.

1. All of the food that we eat — including meat — begins with the growth of plants.
   (a) What is the name of the chemical reaction that produces the glucose that plants produce?
   (b) Which form of energy is necessary to allow this chemical reaction to take place?
2. The baking of bread makes use of a chemical reaction involving yeast and sugar. The same type of reaction is used in brewing to produce alcohol.
   (a) What is the name of this chemical reaction?
   (b) One of the products of this chemical reaction causes bread to rise while it is being baked. What is the name of this product? (*Clue:* It's a gas.)
3. The chemical digestion of food occurs when chemicals in your body react with the food.
   (a) What name is given to the chemicals that speed up these chemical reactions?
   (b) Much of the food that you eat is broken down into glucose, which takes part in a chemical reaction that occurs in every single cell of your body. What is the name of this chemical reaction, which releases useful energy?
4. Overeating can make your stomach produce too much acid.
   (a) Which type of substance is contained in the products that can be taken to reduce the discomfort and pain caused by the extra acid?
   (b) What is the name of the chemical reaction that provides you with relief from the effects of the extra acid?



Evidence of chemical reactions

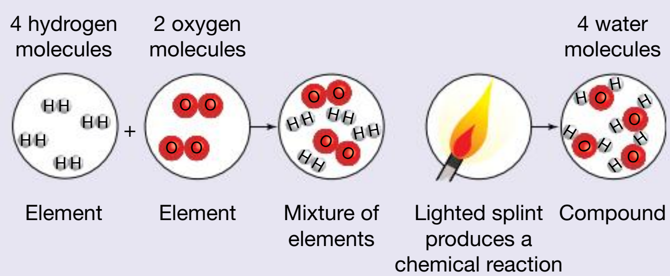
1. Consider the following everyday changes:
   - A silver bracelet will tarnish and become black
   - A cake rises in an oven as it is cooked
   - Butter melts when left out on a counter
   - A candle burns
   - A bath bomb fizzes when it is added to the water in a bathtub
   - Instant coffee dissolves when you add water to it
   - Condensed milk heated in a pan until it forms caramel.

   (a) Which of these changes do you think are chemical reactions?
   (b) For each of the changes you selected in (a), what evidence indicates that a chemical reaction has occurred?
   (c) How is a chemical reaction different to a physical change?
   (d) Give three examples of chemical reactions that you encounter in the bathroom.

Inside chemical reactions

Chemical reactions take place when the bonds between atoms are broken and new bonds are formed, creating a new arrangement of atoms and therefore at least one new substance.

1. Explain what happens to the chemical bonds during the chemical reaction between oxygen and hydrogen as illustrated in the diagram at right.



7.2 Describing chemical reactions

7.2.1 Chemistry word equations

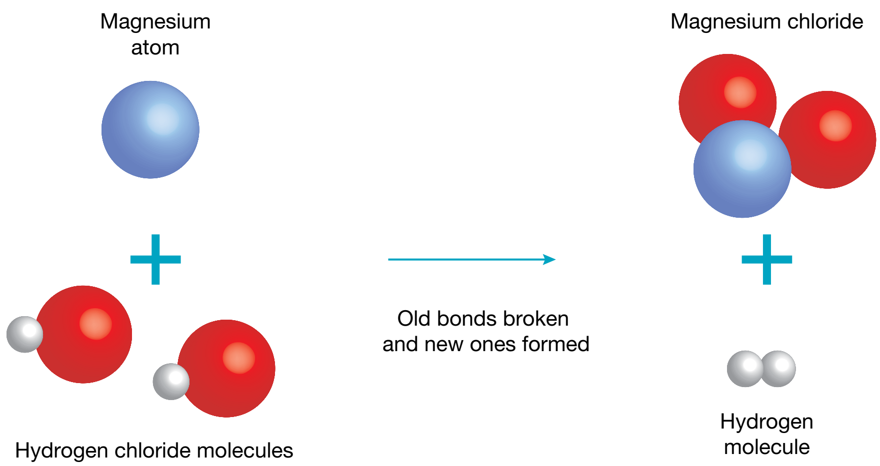
Chemical reactions occur when the bonds between atoms are broken and new bonds are formed creating new combinations of atoms. In fact, once a new substance has been formed it is signalled by observable changes — a change in temperature or colour, the formation of a precipitate or a gas, perhaps even just a different smell being given off. So when you stick some sherbet in your mouth and you feel it fizzing on your tongue, or smell the exhaust fumes from a passing car, you are observing evidence that a chemical reaction has taken place.

You may recall from your previous studies that chemical reactions can be communicated in the form of a chemical equation. The substances that react together are called the **reactants** while the new substances that are formed are called the **products**.

Chemical equations are written so that the reactants are shown first and are separated by a plus sign (+). The reaction itself is represented by an arrow that points to the products of the reaction (→). The products are also separated by plus signs.

For example, when hydrogen gas is added to oxygen gas and ignited, a new substance, water, is formed. We can represent this in the form of a word equation as shown:

$$\textbf{hydrogen gas + oxygen gas} \xrightarrow{\textbf{heat}} \textbf{water}$$



In any chemical reaction, the bonds between the atoms of the reactants have been broken and new bonds formed. In the case of the reaction between hydrogen and oxygen, the covalent bonds between the hydrogen atoms that make up hydrogen gas molecules and the covalent bonds between the oxygen atoms that make up oxygen gas molecules have been broken; the hydrogen and oxygen atoms have then formed new covalent bonds between them to form water molecules. (*Note:* To brush up on bonds, go back to topic 5.)

Notice that the same atoms are present in both the reactants and the products; that is, no new atoms have been introduced during the reaction. The atoms that were present at the beginning of the reaction are still the same ones present at the end. The reaction has simply been a rearrangement of the atoms.

No doubt all of this seems pretty obvious to you, but when the basic mechanics of chemical reactions were first proposed over 200 years ago, this was all very revolutionary.

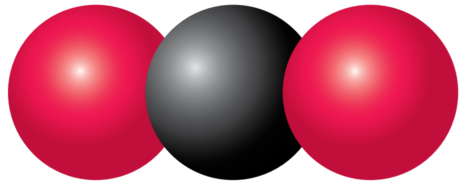
A burning question

In the eighteenth century, Antoine-Laurent Lavoisier provided the evidence on which these ideas are based. He first considered the way in which a candle seems to disappear as it burns. He did a series of experiments in which he captured all of the gases and soot produced as the candle burned and added their mass to the remaining mass of the candle and melted wax. Lavoisier found that the mass of all of the products produced during the candle's burning was equal to the mass of the original candle. Lavoisier's ideas led to the development of the *Law of Conservation of Mass*, which states that *matter can be neither created nor destroyed during a chemical reaction*.

Lavoisier also provided evidence for the *Law of Constant Proportions*, which states that *a compound, no matter how it is formed, always contains the same relative amounts of each element*.

For example, carbon dioxide (CO_2) always contains the same proportion of carbon and oxygen — about 3 grams of carbon for every 8 grams of oxygen. It does not matter whether the carbon dioxide forms from the reaction of sherbet in your mouth, or from the reaction in the engine of a motorcycle, this proportion is fixed because every molecule of CO_2 is formed when one carbon atom bonds with two oxygen atoms. This law helped to shape our understanding of the way atoms bond together.

A carbon dioxide molecule always contains one carbon atom (black) and two oxygen atoms (red).



Kick-starting reactions

Simply placing two chemicals together does not always mean they will react. For example, hydrogen and oxygen react violently, yet a mixture of these two gases can be stored indefinitely if kept cool in a secure container. Energy must be supplied to start these reactions. Sometimes only a small amount of energy is needed to start (or *initiate*) the reaction. Heat transferred from the surroundings may be enough. Energy may also need to be supplied by an electric current, a beam of light or a Bunsen burner flame. This energy is needed to begin the process of breaking the bonds in the reactants, which allows the atoms to rearrange themselves and form new bonds in the products.

In this case, the word equation is modified to show the word 'heat' written over the reaction arrow:

$$\textbf{hydrogen + oxygen} \xrightarrow{\textbf{heat}} \textbf{water}$$

INVESTIGATION 7.1

Conserve that mass!

AIM: To carry out a quantitative experiment that demonstrates the Law of Conservation of Mass

You will need:

safety glasses
250 mL conical flask
4 Alka-Seltzer tablets
1 balloon
matches
an electronic balance
100 mL measuring cylinder
water

CAUTION: Wear safety glasses.

- Place the conical flask on the balance and pour in approximately 100 mL of water.
- Place two tablets alongside the conical flask and record the total mass.
- Remove the flask from the balance and drop the tablets into the water. When the reaction is complete, weigh the flask and record the mass.
- Rinse out the flask thoroughly and again add approximately 100 mL of water.
- Place two tablets and a balloon alongside the conical flask and record the total mass.
- Remove the flask from the balance and drop the tablets into the water. Quickly place the balloon on the flask.
- When the reaction is complete, weigh the flask and record the mass. **Do not remove the balloon**.
- After you have recorded the mass, remove the balloon. Light a match and test the gas. Record your observations.

Discussion

1. Describe what happened during the reaction.
2. Which gas do you think filled the balloon?
3. Comment on your results of the total mass before and after each reaction. Explain your answer.
4. Why do you think it took a long time for the Law of Conservation of Mass to be developed?

HOW ABOUT THAT!

In 1937, a hydrogen-filled airship called the *Hindenburg* exploded violently while docking at a refuelling tower. Until recently, it was believed that hydrogen was the cause of the disaster — hydrogen and oxygen react explosively when ignited by a spark. However, scientists now claim that it was, in fact, the flammable aluminium-coated skin of the airship and a stray spark that were to blame. Use the Hindenburg weblink in your Resources section to listen to reporter Herb Morrison's eyewitness account of the *Hindenburg* explosion.

7.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** the name for chemicals that: (a) combine in a reaction; (b) are formed in a chemical reaction.
2. **Describe** what happens to the atoms in substances that take part in chemical reactions.
3. State the Law of Conservation of Mass and **explain** in your own words what it means.
4. **Recall** the Law of Constant Proportions.
5. Energy can be required to start a reaction. **Recall** three possible sources of this energy.

Think

6. A piece of paper is weighed on an accurate balance, and then burnt, leaving a pile of ashes. The ashes are collected and weighed on the same balance. Would you expect the mass of the ashes to be the same as the mass of the paper before it was burnt? **Explain** your answer in terms of the products produced.
7. **Explain** how, when a piece of steel wool burns, the mass of the blackened material is greater than the original mass of the steel wool.
8. When a piece of sodium metal is added to a trough of cold water, a rapid and energetic reaction occurs.
   (a) **Explain** where the energy to initiate the reaction comes from.
   (b) Is energy absorbed or released in this reaction?
9. A chemical reaction is described by the following word equation:

   sodium sulfate + barium chloride →
   barium sulfate + sodium______

   Identify the name of the second product.
10. The picture at right shows what happens when you add lead nitrate (which is colourless) to potassium iodide (which is also colourless). **Explain** where the yellow substance came from.

Investigate

11. Find out more about Antoine-Laurent Lavoisier, his work and why he lost his head during the French Revolution.

learnON RESOURCES — ONLINE ONLY

Explore more with this weblink: Hindenburg

7.3 The language of chemical equations

7.3.1 Writing chemical equations

In order to communicate, people need to speak a common language. Chemists also use a common language to communicate with each other — a chemical language made up of chemical equations instead of sentences and chemical formulae in place of words!

In topic 5, we learned how to write chemical formulae for ionic and covalent compounds. These chemical formulae indicate the numbers of atoms of each element present in a particular compound.

The chemical formulae of compounds obey the Law of Constant Proportions. That is, every compound has a fixed relative number of each type of atom. For example, all pure water (H_2O) has two hydrogen atoms for every oxygen atom. Sodium chloride (NaCl) has one sodium atom for each chlorine atom. The formula for copper sulfate is $CuSO_4$ because for every copper atom there is one sulfur atom and four oxygen atoms.

So far, we have just used word equations to describe chemical reactions. Now, we will move on to using the appropriate chemical formulae for the reactants and the products in a chemical equation.

Writing equations involves some simple mathematics and a knowledge of chemical formulae. Chemical equations are set out in the same way as word equations, with the reactants to the left of the arrow and products to the right of the arrow. However, they are different from word equations in three ways:

1. formulae are used to represent the chemicals involved
2. the physical states of the chemicals are often included
3. numbers are written in front of the formulae in order to balance the numbers of atoms on each side of the equation.

There are a few rules to observe in this game of balancing equations. They are described below with a worked example of the explosive reaction between hydrogen gas and oxygen gas. Make sure you read through the rules very carefully before you play the game.

GAME RULES

GAME RULE 1. Know your products

The products of a reaction must be known from either **observation** or reliable sources (such as chemists) to tell us the products. For example, it is well known that the product of the reaction between hydrogen gas and oxygen gas is water vapour (gas).

GAME RULE 2. Know your formulae

You need to know the formulae of all the reactants and products. For example:

- formula of hydrogen gas H_2
- formula of oxygen gas O_2
- formula of water vapour H_2O.

Remember! Because each substance has only one correct chemical formula, it cannot be changed by altering the subscript numbers.

GAME RULE 3. Write down the formulae

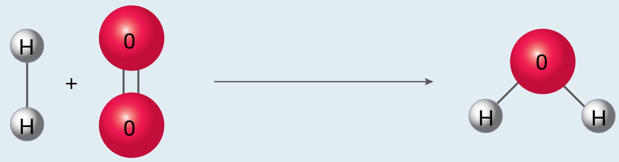
The formulae must be written according to the word equation, with reactants on the left-hand side of the arrow and products on the right-hand side.

$$\mathbf{H_2 + O_2 \rightarrow H_2O}$$

GAME RULE 4. Balance the numbers of atoms

First, make a list of the elements present in the formulae under the heading ‘Element’, as shown on the next page. Then count up how many atoms are represented by the formula of each element under the headings ‘Reactants’ and ‘Products’.

Element	Reactants	Products
H	2	2
O	2	1

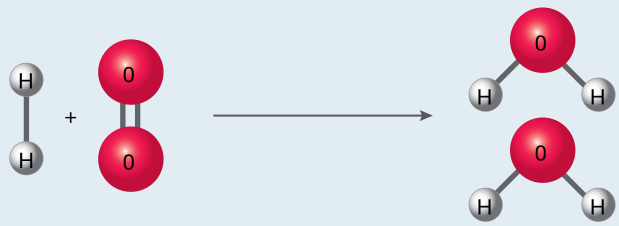


You can see that there are not enough oxygen atoms on the product side of the equation. The only way this can be adjusted is by writing numbers in front of the chemical formulae. When we write a number **in front** of a formula, it **multiplies all the atoms** in that formula. Let's increase the number of oxygen atoms on the product side by placing a 2 in front of the formula for water.

$$\mathbf{H_2 + O_2 \rightarrow 2H_2O}$$

Recounting the atoms we find:

Element	Reactants	Products
H	2	4
O	2	2



The oxygen atoms are now balanced, but the hydrogen atoms are not. Let's try writing a 2 in front of hydrogen's formula on the reactant side to increase the number of hydrogen atoms.

$$\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$$

Counting the atoms again we find:

Element	Reactants	Products
H	4	4
O	2	2

The numbers of each of the elements are the same on both sides of the equation. The equation is balanced!

GAME RULE 5. Include the states

To indicate the physical state of each chemical involved in the reaction, the following symbols are used.

- Solid (s)
- Liquid (l)
- Gas (g)

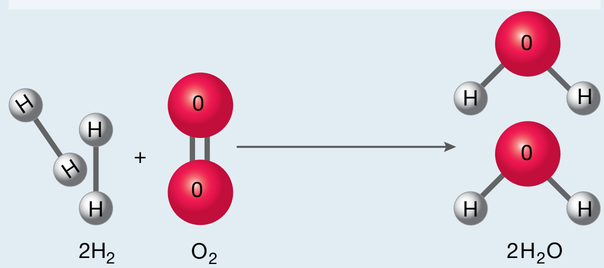
The symbol (aq) is used to represent an **aqueous solution** of a substance. An aqueous solution is obtained when a substance is dissolved in water.

Write the correct symbol representing the physical state of each reactant and product:

$$\mathbf{2H_2(g) + O_2(g) \rightarrow 2H_2O(l).}$$

Formulae correct!
Number of atoms balanced!
States correct!
Formula equation complete!
Game over!

The reaction between hydrogen and oxygen



PLAY THE GAME

- Write a word equation and an equation using formulae for each of the six reactions listed. An example is provided on the next page. See the tables on the next page for the correct formulae.

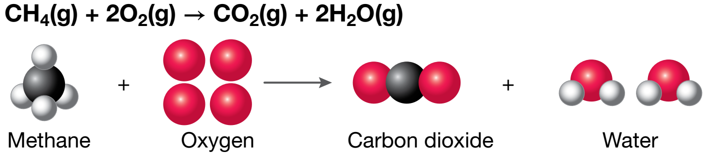
1. Carbon monoxide gas and oxygen gas react to form carbon dioxide gas.
2. Sodium hydroxide solution and hydrochloric acid solution react to form sodium chloride solution and water.
3. Mercury metal and oxygen gas react to form solid mercury(II) oxide.
4. Magnesium metal and hydrochloric acid solution react to form hydrogen gas and magnesium chloride solution.
5. Sodium metal and water react to form hydrogen gas and sodium hydroxide solution.
6. Copper sulfate solution and sodium hydroxide solution react to form solid copper hydroxide and sodium sulfate solution.

The formulae of some common ionic compounds

Compound	Formula
Sodium hydroxide	$NaOH$
Sodium chloride	$NaCl$
Magnesium chloride	$MgCl_2$
Copper hydroxide	$Cu(OH)_2$
Sodium sulfate	Na_2SO_4
Copper sulfate	$CuSO_4$
Sodium hydrogen carbonate	$NaHCO_3$
Mercury(II) oxide	HgO
Sodium citrate	$C_6H_5O_7Na_3$

The formulae of some common covalent substances

Compound	Formula
Water	H_2O
Citric acid	$C_6H_8O_7$
Carbon dioxide	CO_2
Oxygen	O_2
Hydrochloric acid	HCl
Carbon monoxide	CO
Hydrogen	H_2

<table>
<tr><th>Balancing a chemical equation</th><th>Example (Methane gas will burn in air. This is an example of a combustion reaction. This type of reaction produces CO_2 and H_2O.)</th></tr>
<tr><td>Step 1: Start with the word equation and name all of the reactants and products.</td><td>Methane gas + oxygen gas → carbon dioxide + water</td></tr>
<tr><td>Step 2: Replace the words in the word equation with formulae and rewrite the equation.</td><td>Methane gas = CH_4 Oxygen gas = O_2 (reactants)
Carbon dioxide = CO_2 Water vapour = H_2O (products)
$\mathbf{CH_4 + O_2 \rightarrow CO_2 + H_2O}$</td></tr>
<tr><td>Step 3: Count the number of atoms of each element (represented by the formulae of the reactants and products).</td><td><table><tr><th>Element</th><th>Reactants</th><th>Products</th></tr><tr><td>C</td><td>1</td><td>1</td></tr><tr><td>H</td><td>4</td><td>2</td></tr><tr><td>O</td><td>2</td><td>3</td></tr></table></td></tr>
<tr><td>Step 4: If the number of atoms of each element is the same on both sides of the equation, the equation is already balanced. If not, numbers need to be placed in front of one or more of the formulae to balance the equation. These numbers are called coefficients and they multiply all of the atoms in the formula.</td><td>To balance the hydrogen atoms, put a 2 in front of H_2O:
$\mathbf{CH_4 + O_2 \rightarrow CO_2 + 2H_2O}$.
The oxygen atoms can be balanced by putting a 2 in front of the O_2 on the left:
$\mathbf{CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O}$.
The equation is now balanced. It can be checked by counting the number of atoms of each element on both sides of the new equation.<table><tr><th>Element</th><th>Reactants</th><th>Products</th></tr><tr><td>C</td><td>1</td><td>1</td></tr><tr><td>H</td><td>4</td><td>4</td></tr><tr><td>O</td><td>4</td><td>4</td></tr></table></td></tr>
<tr><td>Step 5: Add physical state symbols.</td><td>$\mathbf{CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)}$

</td></tr>
</table>

7.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Describe** three differences between word equations and equations in which formulae are used.
2. **Recall** how different states (solid, liquid and gas) are indicated in a chemical equation.
3. **Define** the term 'aqueous solution' and describe how it is represented in a chemical equation.
4. Write balanced chemical equations for the following reactions:
   (a) hydrochloric acid reacts with copper to form copper chloride and hydrogen
   (b) water and sodium nitrate are formed when nitric acid reacts with sodium hydroxide.

Think

5. **Identify** what symbols you would use in a chemical equation to represent the metals: iron, mercury, zinc and aluminium (both chemical symbol and state).
6. Write a balanced equation using formulae for the reaction that occurs when you eat a sherbet lolly. These sweets commonly contain citric acid and sodium hydrogen carbonate. In the mouth, these chemicals dissolve in your saliva and then react together to form sodium citrate solution, carbon dioxide gas and water.
7. **Explain** why it is necessary to balance chemical equations.
8. Test your ability to balance chemical equations by completing the **Checking for balance** interactivity in the Resources tab.
9. To learn more about balancing chemical equations use the **Balancing equations** weblink in the Resources tab.

learnon RESOURCES — ONLINE ONLY

Try out this interactivity: Checking for balance (int-0677)

Explore more with this weblink: Balancing equations

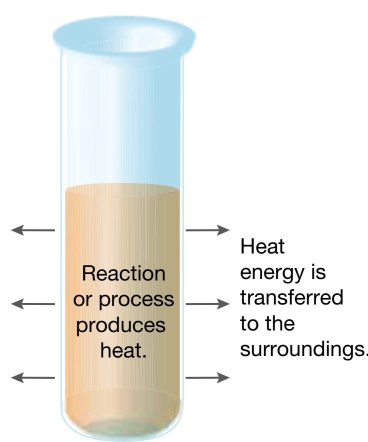
Complete this digital doc: Worksheet 7.1: Chemical equations (doc-12773)

Complete this digital doc: Worksheet 7.2: Balancing chemical equations (doc-12774)

7.4 Hot and cold changes

7.4.1 Bringing on the heat

When chemical reactions occur, bonds are broken between the atoms of the reactants and new bonds are formed when the atoms reform into the product molecules. The breaking and reforming of bonds involves energy being released or absorbed. Often, when a chemical reaction is taking place, you can feel the effect of these energy changes as a change in temperature of the chemicals.



A reaction or process that gives out heat is said to be **exothermic**. The term exothermic comes from the Greek words *exo* meaning 'outside' and *therme* meaning 'heat'. An exothermic process may be the production of new substances in a chemical reaction, the dissolving of a substance, the crystallisation of a substance or the change in state a substance undergoes when it turns from a gas into a liquid or from a liquid into a gas. The energy produced is called **thermal** energy. The thermal energy produced in an exothermic reaction comes from the chemical energy stored in the bonds between the atoms of the reactants. When these bonds break, the energy is released.

Exothermic processes are used in a number of different heat packs that can be used for warming when there is no easy access to electricity. Some of these processes involve chemical reactions while others are physical changes. These heat packs may be used to keep hands warm in a cold environment or to warm muscles before athletics or physiotherapy in case of injury.

One type of heat pack contains iron powder, sawdust, salt, charcoal and water. When the pack is shaken, the iron combines with the oxygen in the air to form iron oxide:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

The sawdust absorbs and spreads the heat in the same way that wheat does in heat bags that are heated in the microwave. The energy produced by this chemical reaction can keep the pack warm for up to 20 hours.

Some exothermic processes are not chemical reactions because no new substance has been formed. Instead, heat is released by the breaking or formation of bonds caused by the rearrangement of the compound molecules into new forms or states of matter.

Pocket warmers use an exothermic process to produce heat.

Most of the pocket warmers that are sold in camping stores are filled with sodium acetate and have a small metal disc inside. When the metal disk in the pocket warmer is cracked, small crystals of sodium acetate are released into the sodium acetate solution in the bag. The solution in the bag is **supersaturated** — that means that it has more solute dissolved in it than normal. When the crystals enter the solution, it triggers **crystallisation** in the solution, releasing thermal energy. This causes the pocket warmer to heat and keep your pockets — and the hands in them — toasty warm for a few hours. This is described as an exothermic process rather than an exothermic reaction as no new substances are formed.

Yet another type of heat pack contains calcium chloride powder in a bag with an inner bag of water. When the bag of water bursts, heat is released as the bonds between the atoms in the calcium chloride break, forming ions of calcium and chlorine which then spread throughout the water, forming an aqueous solution of calcium chloride:

$$CaCl_2(s) \xrightarrow{\text{water}} CaCl_2(aq)$$

INVESTIGATION 7.2

Exothermic processes

AIM: To investigate some reactions that produce heat

You will need:

3 large test tubes and test-tube rack
10 mL measuring cylinder
balance
spatula and watch glass
thermometer (–10 °C to 110 °C)

stirring rod
magnesium ribbon
sandpaper
0.5 M hydrochloric acid
0.5 M sodium hydroxide
anhydrous copper(II) sulfate

Construct a table, like the one below, to record the temperature changes in each of the following experiments.

CAUTION: Wear safety glasses.

Part 1: Magnesium in hydrochloric acid

- Put 10 mL of 0.5 M hydrochloric acid in a test tube and place it in the test-tube rack. Place a thermometer in the test tube and record the temperature.
- Clean a 5 cm piece of magnesium ribbon with the sandpaper until it is shiny on both sides. Coil the magnesium ribbon and put it in the test tube of hydrochloric acid.
- Record the final temperature of the solution as the magnesium reacts with the hydrochloric acid.

Part 2: Hydrochloric acid and sodium hydroxide

- Put 10 mL of 0.5 M hydrochloric acid in a test tube and place it in the test-tube rack.
- Place a thermometer in the test tube and record the temperature.
- Add 10 mL of 0.5 M sodium hydroxide solution to the test tube and record the final temperature of the solution as the hydrochloric acid reacts with the sodium hydroxide.

Part 3: Dissolving anhydrous copper(II) sulfate in water

- Put 10 mL of water in a test tube and place it in the test-tube rack. Record the temperature of the water.
- Use a balance to weigh out 2 g of anhydrous copper(II) sulfate. Add this to the test tube and stir gently.
- Record the final temperature of the solution as the copper(II) sulfate dissolves.

Discussion

1. Complete the table by calculating the increase of temperature in each case.
2. Sometimes the energy given out is described as the heat of reaction and in other cases it is called the heat of solution. For each of the above, decide in which category they belong.

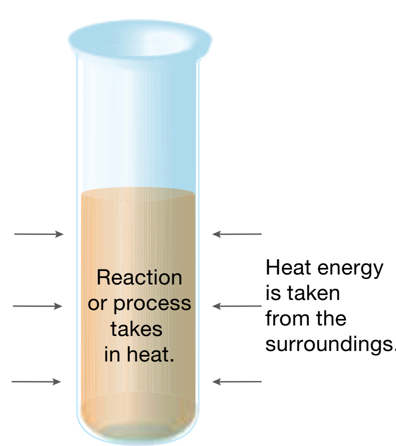
Exothermic processes

Chemical process	Initial temperature (°C)	Final temperature (°C)	Increase in temperature (°C)

7.4.2 Cooling it!

Endothermic reactions are the opposite of exothermic reactions. These reactions take in thermal energy from their environment in order to make or break the chemical bonds between atoms. Because they remove heat from their environment, endothermic reactions reduce the temperature of the reacting chemicals.

As with exothermic processes, endothermic processes can be chemical reactions, or physical changes such as when a substance is dissolved or when there is a change of state. Some reactions can get so cold that water vapour from the air freezes on the outside of the container. This type of reaction can come in very handy at times.



INVESTIGATION 7.3

Endothermic processes

AIM: To investigate some reactions that absorb heat from their surroundings

You will need:

3 large test tubes and a test-tube rack
10 mL measuring cylinder
balance
spatula and watch glass
thermometer (–10 °C to 110 °C)
stirring rod
potassium nitrate
sodium thiosulfate.

For class demonstration:

barium hydroxide octahydrate
ammonium thiocyanate
2 × 250 mL beakers
stirring rod
electronic thermometer
wooden block
wash bottle.

Construct a table like the one below in which to record the temperature changes in each of the following experiments.

CAUTION: Wear safety glasses.

Part 3 is a class demonstration using a fume hood. Ammonia is one of the products.

Endothermic processes

Chemical process	Initial temperature (°C)	Final temperature (°C)	Decrease in temperature (°C)

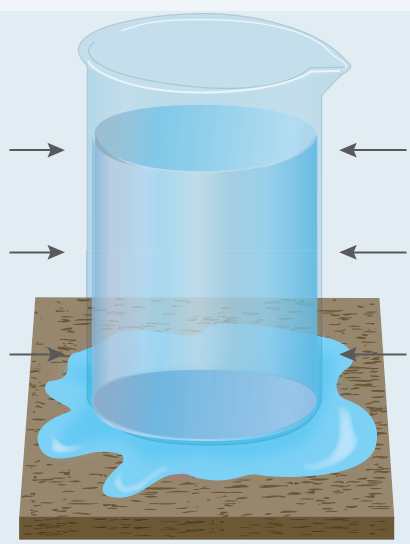
Part 1: Dissolving potassium nitrate in water

- Put 10 mL of water in a test tube and place it in the test-tube rack. Record the temperature of the water.
- Use a balance to weigh out 2 g of potassium nitrate. Add this to the test tube and stir gently. Record the final temperature of the solution as the potassium nitrate dissolves.

Part 2: Dissolving sodium thiosulfate in water

- Put 10 mL of water in a test tube and place it in the test-tube rack. Record the temperature of the water.
- Use a balance to weigh out 2 g of sodium thiosulfate. Add this to the test tube and stir gently.
- Record the final temperature of the solution as the sodium thiosulfate dissolves.

Ammonium thiocyanate is mixed with barium hydroxide.



Part 3: Class demonstration — barium hydroxide octahydrate and ammonium thiocyanate

- Use a balance to weigh out 32 g of barium hydroxide octahydrate into a beaker and record its temperature. Place in the fume hood.
- Using a second beaker, weigh out 17 g of ammonium thiocyanate.
- In the fume hood, mix the ammonium thiocyanate into the first beaker and, using a stirring rod, blend the two solids.
- Squirt some water on the wooden block and sit the beaker on the block.
- Record the final temperature of the mixture with an electronic thermometer.

Discussion

1. Complete the table by calculating the decrease of temperature in each case.
2. In which of the above were new substances produced?
3. Which of the above were (a) chemical reactions (b) physical changes?

Ice on tap

Athletes use the endothermic processes in instant ice packs to cool injured or swollen muscles. One type of icepack has powdered ammonium nitrate in a bag with an inner bag of water. When the bag of water is burst, the ammonium nitrate dissolves in the water and then draws energy from its surroundings, making the icepack cold. When held against the body, the icepack draws heat from the injured area. This process is described by the equation:

$$NH_4NO_3(s) \xrightarrow{\text{water}} NH_4NO_3(aq)$$

Remember that, as no new substances have been formed, this is not actually a chemical reaction.

7.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. How are exothermic reactions different from endothermic reactions?
2. In a chemical reaction in which energy is absorbed from the surroundings, where does the extra energy go?
3. **Explain** why the chemical process that takes place in an icepack containing ammonium nitrate is not a chemical reaction.
4. **Explain** what the term supersaturated means.

Think

5. The exothermic reaction produced in pocket warmers can be reversed by placing the bag in hot water. What do you think you would see happening in the bag during this time?
6. **Explain** why the combustion (burning) of methane is an exothermic reaction.
7. Are the chemical reactions described below exothermic or endothermic?
   (a) Dilute hydrochloric acid is added to dilute sodium hydroxide in a test tube. They react to produce sodium chloride and water. After the reaction, the test tube feels very warm.
   (b) As garden compost decomposes, the compost heap gets warmer.
   (c) Barium hydroxide and ammonium thiosulfate solutions are mixed and the temperature drops enough to freeze water.

8. Instant hot compresses are used by athletes to warm torn muscles. They relieve pain and speed up the healing process. Some of these hot compresses contain calcium chloride powder and an inner bag of water. When the inner bag bursts, the calcium chloride dissolves in the water and releases energy.
   (a) Is the chemical process that takes place in the compress endothermic or exothermic?
   (b) How does the energy stored in the chemical bonds of the product compare with the energy stored in the chemical bonds of the calcium chloride and water?
   (c) Write an equation to describe this process.
9. Are explosions endothermic or exothermic reactions? **Explain** your answer.
10. In exothermic chemical reactions, energy is released. Why is energy not included in the chemical equations that describe the reactions?

Investigate

11. Alfred Nobel, the Swedish chemist, made the explosive nitroglycerine much safer.
    (a) Use the internet to find out how he did this.
    (b) Why did he have to move his laboratory?
    (c) What did Alfred Nobel do with his fortune? Why?
12. Use a yearbook or the internet to find out who won the most recent Nobel prizes for Chemistry, Physics and Medicine. Write a short biography about one of the laureates. (The winners of Nobel prizes are referred to as laureates. The Nobel prizes are announced in October of each year.)

7.5 Acids and bases

7.5.1 Acids

Chemical reactions involving acids and bases play an important role in our lives. They occur in the kitchen, in the laundry, in the garden, in swimming pools and even inside the body. This unit revises your knowledge about acids, bases and neutralisation reactions.

Acids are corrosive substances. That means that they react with solid substances including metals, marble and even the enamel of your teeth, effectively 'eating' them away. When strong acids such as the sulfuric acid used in car batteries come into contact with the skin, they break down the proteins and fats in the living tissues. This reaction is exothermic so the area heats up dramatically. At best, the result is an acid burn that is slow to heal.

However, not all acids are strong acids. The weaker acids in ant and bee stings may cause pain but there is little lasting damage to the tissues around the sting site. Others, like the acids in citrus fruits and vinegar, are safe — even pleasant — to taste. Acids such as these are routinely added to food to give it the distinctive sour taste associated with acids — in fact, the word 'acid' comes from the Latin word *acidus* meaning sour. Acids can also be used to preserve food or to react with other substances in food to produce carbon dioxide gas which makes foods like sponge cake light and fluffy.

7.5.2 Bases

Bases have a bitter taste and feel slippery or soapy to touch. Some bases are very corrosive, especially caustic soda which will break down fat, hair and vegetable matter. Other bases are used in shampoos, toothpaste, and cleaning agents like dishwashing liquid and cloudy ammonia. Bases that can be dissolved in water are called alkalis.

Describing acids and bases

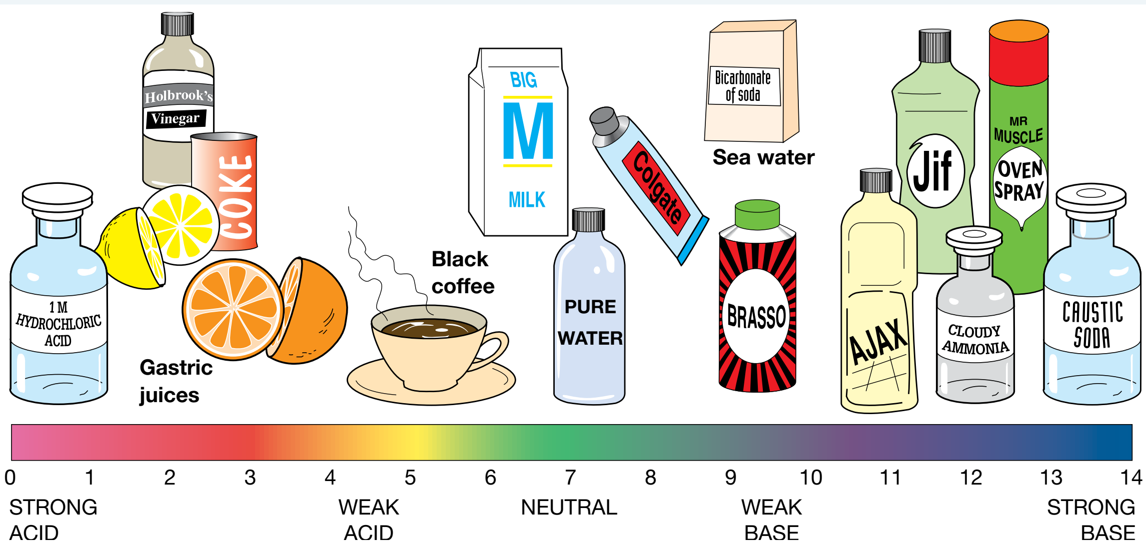
You can describe how acidic or basic a substance is by using the numbers on the pH scale. The pH scale ranges from 0 to 14. Low pH numbers (less than pH 7) mean that substances are acidic. High pH numbers (more than pH 7) mean that substances are basic. If a substance has a pH of 7 it is said to be **neutral** — neither acidic nor basic. This is shown on the pH scale on next page. Acids and bases can be graded from strong to weak. For example, a strong acid has a very low pH (pH 0 or 1) and a strong base has a very high pH (pH 13 or 14).

Common acids and bases

Acid	Uses
Hydrochloric acid	• To clean the surface of iron during its manufacture • Food processing • The manufacture of other chemicals • Oil recovery
Nitric acid	• The manufacture of fertilisers, dyes, drugs and explosives
Sulfuric acid	• The manufacture of fertilisers, plastics, paints, drugs, detergents and paper • Petroleum refining and metallurgy
Citric acid	• Present in citrus fruits such as oranges and lemons • In the food industry and in the manufacture of some pharmaceuticals
Carbonic acid	• Formed when carbon dioxide gas dissolves in water: present in fizzy drinks
Acetic acid	• Found in vinegar • In the production of other chemicals, including aspirin

Base	Uses
Sodium hydroxide (caustic soda)	• In the manufacture of soap • As a cleaning agent
Ammonia	• In the manufacture of fertilisers and in cleaning agents
Sodium bicarbonate	• To make cakes rise when they cook

The pH values of some common substances



7.5.3 Measuring pH

The pH of a substance can be measured using a pH meter or liquids called **indicators**. Indicators change colour depending upon the pH of the substance in which they are placed. The colour ranges of a number of different indicators over the pH range 1–10 are shown on the next page.

Universal indicator is a mixture of indicator substances that changes colour over the full range of pH from 1 to 14 as the strength of an acid or base changes. It is pink in strong acid (pH 1), blue in strong base (pH 14) and green in neutral solutions (pH 7).

A pH meter measures the number of hydrogen ions that are in the liquid and uses this to calculate the pH which is displayed on the screen.

Different indicators respond to different ranges of pH.

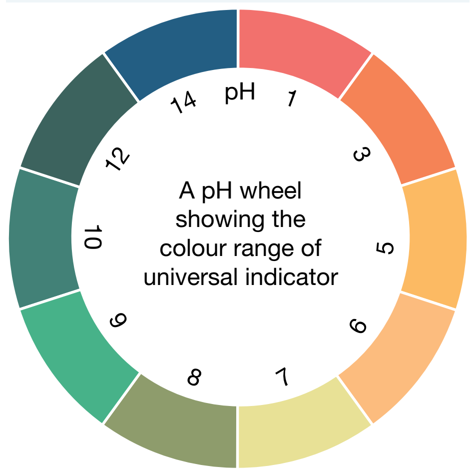
7.5.4 Neutralisation

To neutralise something means to stop it from having an effect. Acids and bases are able to counteract or neutralise each other. To stop acid from having an effect, a base can be added to it. For example, the pain caused by the acidic sting of an ant can be relieved by washing the area with an alkali solution containing a weak base such as sodium bicarbonate (baking soda). Similarly, to stop a base from having an effect, an acid can be added. This is why the pain caused by the alkali in the sting of a wasp can be relieved by pouring a weak acid such as vinegar over the area.

When an acid and a base react with each other, the products are water and a salt (and sometimes a gas) which are neutral (pH7). As a result, such a reaction is called a neutralisation reaction. When hydrochloric acid reacts with sodium hydroxide, water and the salt sodium chloride are produced:

$$\mathbf{NaOH(aq) + HCl(aq) \rightarrow H_2O(l) + NaCl(aq)}$$

The colour range of universal indicator. It is pink in strong acid (pH 1), blue in strong base (pH 14) and green in neutral solutions (pH 7).



Neutralisation in action

Indigestion

The hydrochloric acid in your stomach helps to break down the food you eat. It is a very strong acid, with a pH of less than 1.5. But if you eat too quickly, or eat too much of the wrong food, the contents of your stomach become even more acidic. You feel a burning sensation because of the corrosive properties of the acid.

Some people drink bicarbonate of soda dissolved in water to

neutralise the acid. However, this produces carbon dioxide gas which builds up in the stomach, making these people feel very uncomfortable and having to burp a lot to relieve the pressure of the gas.

$$\begin{array}{llllll} \mathbf{NaHCO_3(aq)} & \mathbf{+\ HCl(aq)} & \mathbf{\rightarrow\ NaCl(aq)} & \mathbf{+\ H_2O(l)} & \mathbf{+\ CO_2(g)} \\ \textbf{Sodium hydrogen} & \textbf{+ hydrochloric} & \textbf{→ sodium} & \textbf{+ water} & \textbf{+ carbon} \\ \textbf{carbonate} & \textbf{acid} & \textbf{chloride} & & \textbf{dioxide} \end{array}$$

The most effective way of relieving the indigestion is to take antacid tablets. The active ingredients in modern antacid tablets are weak bases such as aluminium hydroxide or magnesium hydroxide, which neutralise the acid without producing the carbon dioxide gas along with it!

$$\begin{array}{lllll} \mathbf{Mg(OH)_2(aq)} & \mathbf{+\ 2HCL(aq)} & \longrightarrow & \mathbf{MgCl_2(aq)} & \mathbf{+\ 2H_2O(l)} \\ \textbf{Magnesium} & \textbf{+ hydrochloric} & \longrightarrow & \textbf{magnesium} & \textbf{+ water} \\ \textbf{hydroxide} & \textbf{acid} & & \textbf{chloride} & \end{array}$$

$$\begin{array}{lllll} \mathbf{Al(OH)_3(aq)} & \mathbf{+\ 3HCL(aq)} & \longrightarrow & \mathbf{AlCl_3(aq)} & \mathbf{+\ 3H_2O(l)} \\ \textbf{Aluminium} & \textbf{+ hydrochloric} & \longrightarrow & \textbf{aluminium} & \textbf{+ water} \\ \textbf{hydroxide} & \textbf{acid} & & \textbf{chloride} & \end{array}$$

Of course, care should always be taken when using antacid tablets. If you are using these too often, the stomach reacts by making more acid because it needs the acid to digest proteins. If you then suddenly stop taking the antacid tablets, the increased amount of acid can cause serious health problems.

INVESTIGATION 7.4

Antacids in action

AIM: To use an antacid to neutralise dilute hydrochloric acid and monitor the reaction with a pH indicator

You will need:

Petri dish
electronic balance
spatula
antacid powder
0.1 M hydrochloric acid
250 mL conical flask
100 mL measuring cylinder
methyl orange indicator
white tile or white paper

- Measure and record the mass of the Petri dish.
- Add a small amount of antacid powder to the dish and record the mass of the antacid and Petri dish.
- Calculate the mass of the powder.
- Add 50 mL of the dilute hydrochloric acid to the 250 mL flask.
- Add 3 drops of methyl orange indicator.
- Place the flask mixture on the white tile (or paper) and use the spatula to slowly add antacid from the Petri dish bit by bit. Swirl the flask to mix. Stop adding antacid when the colour changes from red to orange.
- Measure and record the mass of the Petri dish and its contents (the unused antacid).

Discussion

1. What was the mass of the antacid powder?
2. What colour change occurs when the methyl orange indicator is in the acid?
3. By subtraction, calculate the mass of antacid used to neutralise 50 mL of dilute hydrochloric acid.
4. How does your result agree with other groups in your class? Suggest reasons for the similarities or differences between your results.
5. Use your results to calculate how much antacid you would need to neutralise 500 mL of dilute hydrochloric acid.

HOW ABOUT THAT!

Indigestion is a very old problem and, with not an antacid tablet in sight, many ancient civilisations developed some very interesting ways of treating it. The Egyptians recommended crushing a hog's tooth and putting it inside four sugar cakes which you would then eat. They also believed that swallowing crushed and powdered limestone would help. Interestingly enough, scientists believe that this last one may have worked because the main component of limestone is calcium carbonate. Favourite treatments in medieval England were a bit yummier and involved chewing mint leaves or drinking teas brewed from thyme or pomegranate peel.

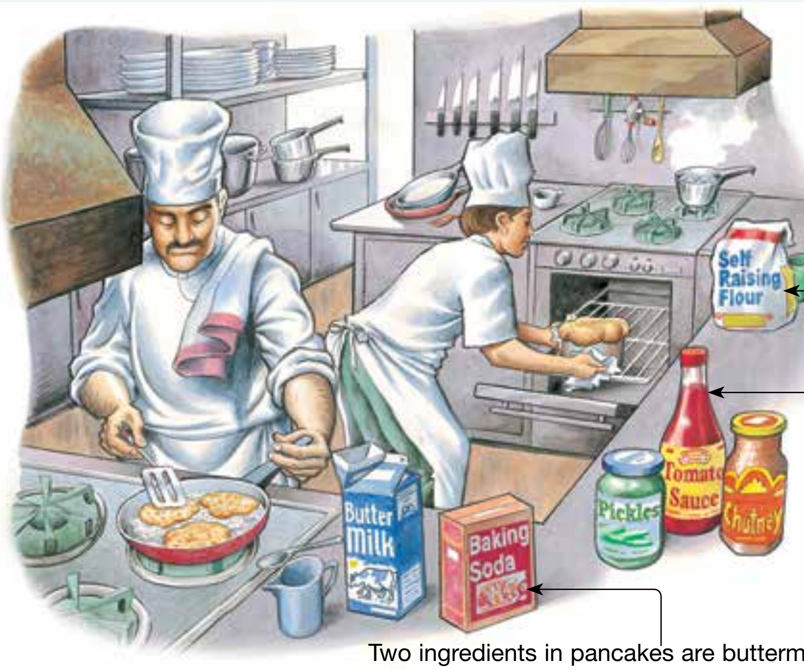
How does your garden grow?

When the soil is too acidic, it can be 'sweetened' (made less acidic) by mixing an alkaline substance called **garden lime** into it. Garden lime is available in a variety of forms usually containing some combination of calcium hydroxide, calcium carbonate or magnesium carbonate that neutralises some of the soil's acidity. Many gardeners prefer the limes that contain magnesium carbonate as plants use magnesium to make the green chlorophyll in their leaves that allows them to perform photosynthesis.

What's cooking?

Many acids and bases are found in the kitchen. They help to preserve food and make foods rise when baking. Acids and bases are also found in cleaners used around the house.

Cooking with acids and bases



Self-raising flour usually contains an acid and baking soda (the base) which react together when water or milk is added. The carbon dioxide produced causes the mixture to rise when it is heated.

Some bottled foods, such as pickles, chutney and tomato sauce, last a long time without spoiling. They contain acids, which keep the pH low enough to stop the growth of bacteria.

Two ingredients in pancakes are buttermilk (an acid) and baking soda (a base). The two mix, producing a salt, water and carbon dioxide. The carbon dioxide bubbles get bigger when the mixture is heated, causing the mixture to rise.

Body basics

Your body uses alkalis to neutralise acidity in various parts of the digestive and excretory system. When food leaves the stomach and passes into the duodenum, it has some of the hydrochloric acid from the stomach mixed into it. This could burn the tender interiors of the intestines further down if not neutralised. To counter this acidity, a greenish-yellow alkali called **bile** is secreted by the gall bladder, entering the duodenum through the bile ducts. Here the bile mixes with the mush of partly digested food and acid and makes it neutral.

In the swim

When chlorine is added to a swimming pool, it reacts with the water to produce hypochlorous acid. This acid kills bacteria and algae, keeping the pool water safe for swimming. All the chemicals in a swimming pool, when combined, need to have a pH in the range of 7.2–7.8 for a clean, hygienic pool and safe swimming.

If the pH falls below 7.2, the micro-organisms will still be killed but the swimmers will get red and stinging eyes, and the water may become corrosive and damage pool fittings. A base such as sodium carbonate (soda ash) or sodium bicarbonate (bicarbonate of soda) would have to be added to neutralise the excess acid.

If the pH rises above 7.8, bacteria and algae will grow and the water will be unfit for swimming. To reduce the pH, an acid such as sodium hydrogen sulfate would have to be added to neutralise the excess base.

HOW ABOUT THAT!

The tastebuds on the human tongue can detect five different kinds of taste — sweet, sour, bitter, salty and savoury. Powdered sherbet stimulates three of these as it is made of sour tasting citric acid, bitter bicarbonate of soda and sweet powdered sugar. When you eat sherbet, the water from your saliva allows a chemical reaction to happen between the citric acid and the bicarbonate of soda to produce carbon dioxide gas that gives a fizzing sensation that you can feel in your mouth.

7.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Distinguish** between acids and bases.
2. What common reaction do some acids and bases have when they come into contact with solid substances?
3. **Describe** the difference between a base and an alkali.
4. **Identify** which type of substance has a pH value: (a) less than 7 (b) more than 7 (c) equal to 7.
5. **Recall** why the chemical reaction between an acid and a base is called neutralisation.
6. **Recall** what is produced in all neutralisation reactions.
7. **Identify** which acid can be found in your stomach.
8. **Explain** how an antacid relieves the pain of indigestion.
9. **Explain** how self-raising flour helps cakes rise.

Using data

10. A pH meter is used to measure the pH of 5 different substances. The results are as shown in the table at right.
    (a) **Identify** which substance is most likely to be: (i) orange juice (ii) milk.
    (b) **Identify** which substance could be: (i) a weak base (ii) pure water (iii) vinegar (iv) a strong base.
    (c) **Identify** which two of the substances you would expect to be the most corrosive.

Substance	pH value
A	6.0
B	12
C	3.0
D	7.0
E	8.0

Think

11. A burning feeling in your stomach is often due to the juices in your stomach becoming too acidic. The treatment for this ‘indigestion’ problem is to take an antacid tablet. Antacid tablets contain a base, which neutralises the excess acid and relieves the pain. When you take an antacid tablet, would you expect the pH value in your stomach to increase or decrease? **Explain** your answer.
12. A stinging-nettle plant maycontain an acid that is injected into your skin when you touch it. **Describe** how you could show that the plant does contain an acid.
13. Write a balanced chemical equation to describe the chemical reaction between hydrochloric acid and calcium carbonate.
14. Why is it that the acids in the food and drink you consume do not damage your stomach?
15. When you add buttermilk (an acid) to baking soda (a base) in a mixing bowl, does the pH increase or decrease? **Explain** your answer.

Investigate

16. On the packet of one brand of baking soda, there is a claim that you can deodorise your entire house by sprinkling it on your carpets and leaving it for a few minutes before vacuuming.
    (a) Suggest how the baking soda could have this deodorising effect.
    (b) **Investigate** other claims made on baking soda packaging and design some experiments to test one or more of the claims.

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Complete this digital doc: Worksheet 7.3: Acids, bases and neutralisation (doc-12775)

7.6 Salty substances

7.6.1 Salts

Tea, coffee, shampoo and baking powder are all examples of household chemicals designed to be used when dissolved in water. Because water is a good **solvent**, it is able to dissolve many other substances. Chemicals which are dissolved are called **solutes**. A **solution** is a mixture of a solute and the solvent in which it is dissolved. Many reactions involving acids and bases occur in water. These reactions are said to occur 'in solution'.

In the previous subtopic, we have seen how the excess stomach acid that causes indigestion can be treated by neutralising it with a base. The reaction between the acid and a base produces water and a salt in a process called neutralisation. Note that we say *a* salt. You may think that there is only one kind of salt — the kind that you put on your fish and chips. In reality, the word salt describes any product of the neutralisation process that contains a positive metal ion and a negative non-metal ion bonded together. So while common table salt (sodium chloride) is indeed a salt in the chemical sense so too are potassium chloride, sodium sulfate and magnesium nitrate.

The base sodium hydrogen carbonate, commonly known as 'bi-carb', is a component of baking powder. It has the formula $NaHCO_3$ and contains the hydrogen carbonate ion HCO_3^-. When bases containing this ion react with acids, the gas carbon dioxide is produced as well as a salt and water. As we saw in the previous subtopic, when hydrochloric acid and bi-carb are mixed together, the following reaction takes place:

$$\mathbf{NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)}$$

base + acid → salt + carbon dioxide + water

HOW ABOUT THAT!

Many salts are brightly coloured and many are highly poisonous and not at all suitable for sprinkling on your fish and chips! Salts containing copper ions are usually blue, those containing nickel are pale green, those containing iron can be green or orange and cobalt salts are pink.

Not all salts can be sprinkled on your fish and chips!

The products are sodium chloride, carbon dioxide and water. In the reaction on the previous page, the salt formed was a metal chloride, because it contains the chloride ion (Cl^-) from the hydrochloric acid. Neutralisation reactions between many different acids and bases are possible; therefore, it is possible to produce many different salts. The names of all these salts are related to the bases and acids from which they are formed. Some of these are summarised in the table below.

Base	Acid	Negative ion present in salt	Salt
Sodium hydroxide	Sulfuric acid	Sulfate SO_4^{2-}	Sodium sulfate
Magnesium oxide	Hydrochloric acid	Chloride Cl^-	Magnesium chloride
Sodium oxide	Acetic acid	Acetate CH_3COO^-	Sodium acetate
Copper(II) oxide	Nitric acid	Nitrate NO_3^-	Copper(II) nitrate

INVESTIGATION 7.5

Pass the salt!

AIM: To produce salt from a neutralisation reaction

You will need:

safety glasses and laboratory coat
50 mL burette
retort stand, bosshead and clamp
tripod and gauze mat
Bunsen burner, heatproof mat and matches
20 mL pipette
100 mL conical flask
pipette bulb
white tile
dropping bottle of phenolphthalein indicator
wire shaped into a loop with a handle
small funnel
1 M hydrochloric acid solution
1 M sodium hydroxide solution
evaporating dish
silver nitrate solution in a dropping bottle
sample of sodium chloride
test tube

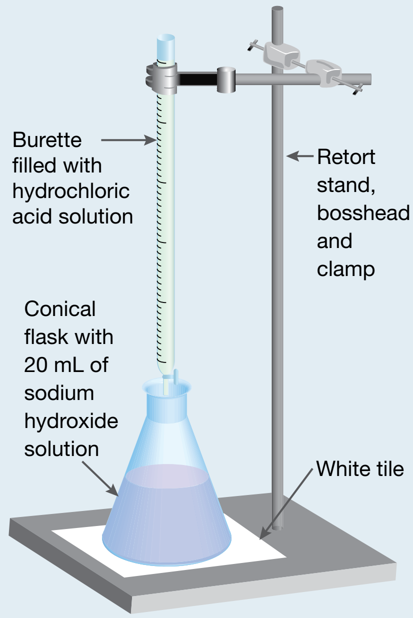
CAUTION: Wear safety glasses and a laboratory coat.

- Rinse the burette with the hydrochloric acid solution and then, using the funnel, fill the burette with the hydrochloric acid solution.
- Rinse the pipette with sodium hydroxide solution using the pipette bulb.

CAUTION: Never pipette using your mouth.

- Set up the equipment as shown in the diagram on next page. Use the pipette and bulb to transfer 20 mL of the sodium hydroxide solution into the conical flask.
- Add a few drops of phenolphthalein indicator to the sodium hydroxide.
- Add the acid from the burette carefully until the pink colour of the indicator disappears. The colour change indicates that the neutralisation reaction is complete.
- Pour the contents of the flask into an evaporating dish. Heat the dish with the Bunsen burner and gently evaporate the water. Be careful — splattering may occur.
- When the water has nearly evaporated, turn off the Bunsen burner and allow the dish to cool and the remaining water to evaporate without further heating.

- Test the white crystals for the presence of sodium ions by placing a few crystals on a wire loop and heating in a Bunsen burner flame. Compare this flame colour with a known sample of sodium chloride. Record your observations.
- Test for the presence of chloride ions by dissolving a few crystals in half a test tube of water and adding a few drops of silver nitrate. A white cloudiness indicates that chloride ions are present. Record your observations.



Discussion

1. Comment on the information that the flame and silver nitrate tests provided. What conclusion can you draw?
2. Write a word equation for the neutralisation reaction.
3. Write a balanced equation, using formulae, for the neutralisation reaction.
4. Design a test to show that water was the other product of the reaction.

7.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Explain** the meaning of the words 'solute', 'solvent' and 'solution'.
2. **Recall** what the expression 'reaction in solution' means.
3. **Define** the term 'salt'.
4. **Recall** the products of a reaction between an acid and a base that contains a hydrogen carbonate ion.

Think

Use the table of neutralisation reactions and the table at right to answer the following questions.

Common laboratory bases	Base formula
Sodium hydroxide	$NaOH$
Copper hydroxide	$Cu(OH)_2$
Magnesium oxide	MgO
Potassium hydroxide	KOH
Magnesium hydroxide	$Mg(OH)_2$
Sodium carbonate	Na_2CO_3
Sodium bicarbonate	$NaHCO_3$

5. Write balanced chemical equations for the following reactions.
   (a) Solid sodium bicarbonate and sulfuric acid react to form a sodium sulfate solution, carbon dioxide and water.
   (b) Solid potassium hydroxide and hydrochloric acid react to form a solution of potassium chloride and water.
   (c) Solid copper oxide reacts with sulfuric acid to form a solution of copper sulfate and water.
6. **Identify** the salts that would form from the reaction between:
   (a) magnesium hydroxide and hydrochloric acid
   (b) potassium hydroxide and acetic acid
   (c) sodium carbonate and sulfuric acid.

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Complete this digital doc: Worksheet 7.4: Neutralisation and salts (doc-12776)

7.7 Precipitation reactions

7.7.1 Presto precipitation!

When table salt (sodium chloride) is dissolved in water to form an aqueous solution, it seems to 'disappear'. The ions in the salt no longer bond together as a large lattice of positive and negative ions like they do as a solid. The sodium ions and the chloride ions separate when they dissolve in water. Because the separated ions are so small, we cannot see them. However, when we evaporate water from the solution we find that sodium chloride crystals are left behind. The dissolving of sodium chloride in water can be represented by the equation:

$$\mathbf{NaCl(s) \xrightarrow{(H_2O)} Na^+(aq) + Cl^-(aq)}$$

Ions in aqueous solutions are therefore separate entities and are able to react independently.

When colourless lead nitrate solution and colourless potassium iodide solution are added together, a brilliant yellow solid is formed. Where does this solid come from? When two solutions containing dissolved ions are mixed together, these ions are able to come into contact with each other. Oppositely charged ions attract. In some cases, the attraction is strong enough to form ionic bonds and hence a new ionic compound. Some of these compounds are insoluble (unable to dissolve in water) and so a solid forms. This solid is called a **precipitate**. Chemical reactions in which precipitates form are called **precipitation reactions**.

Ionic compounds dissolve in water to varying degrees. Some are said to be soluble, others slightly soluble and others insoluble. The following box outlines some handy rules for predicting if a compound is soluble or not.

SOLUBLE OR NOT?

1. All compounds containing either the Na^+, NH_4^+, K^+ or NO_3^- ion will dissolve in water. Compounds containing these ions never form precipitates.
   Example: This rule tells us that NaCl, NH_4Cl, K_2SO_4 and $AgNO_3$ are all soluble in water and therefore do not form precipitates.
2. Compounds containing the Cl^-, Br^- and I^- ions are soluble, except when they contain the Ag^+, Pb^{2+} or Hg^{2+} ions.
   Example: This rule tells us that $FeCl_3$, $ZnBr_2$ and AlI_3 are soluble, but that AgCl, $HgBr_2$ and PbI_2 are not soluble.
3. Compounds containing the SO_4^{2-} ion are soluble, except for $BaSO_4$, $PbSO_4$ and $CaSO_4$.
   Example: This rule tells us that $ZnSO_4$ will dissolve, but $BaSO_4$ will form a precipitate.
4. Compounds containing CO_3^{2-} and PO_4^{3-} are insoluble except when they contain the ions Na^+, NH_4^+ or K^+.
   Example: This rule tells us that $BaCO_3$ will form an insoluble precipitate, but Na_2CO_3 will not.
5. Compounds containing OH^- are insoluble, unless they contain the ions Na^+, NH_4^+ or K^+.
   Example: This rule tells us that $Zn(OH)_2$ will form a precipitate, but NaOH will not.
6. Some compounds are slightly soluble. These include $Ca(OH)_2$, $PbCl_2$, $PbBr_2$, $CaSO_4$ and Ag_2SO_4.

Changing partners

Another example of a precipitation reaction is the one between silver nitrate solution and sodium chloride solution. When these two clear, colourless solutions are added together, the contents of the test tube become cloudy, indicating that a precipitate has formed. If the tube is allowed to stand for a while, the solid settles to the bottom and we can see that a clear solution is also present. The products of the reaction are insoluble solid silver chloride (the precipitate) and sodium nitrate (not visible because it is soluble in water). This reaction can be represented by the equations:

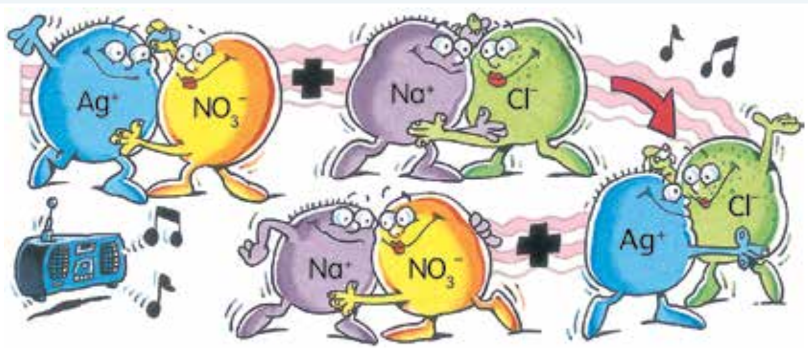
$$\mathbf{AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)}$$

silver nitrate	**+**	**sodium chloride**	**→**	**silver chloride**	**+**	**sodium nitrate**

The box on the previous page indicates that silver nitrate, sodium chloride and sodium nitrate all dissolve in water. Therefore, they have the symbol '(aq)'. Silver chloride does not dissolve in water so it has the symbol '(s)' to indicate that it is solid. The precipitation of silver chloride can be used as evidence of the presence of silver ions in an unknown solution.

The equation above shows that the ions in the reactants have changed 'partners'. The silver ion is paired with the chloride ion on the product side of the reaction and the sodium ion is paired with the nitrate ion. The opposite is the case on the reactant side of the equation. A positive ion can pair up only with a negative ion because oppositely charged ions are attracted to each other. When writing the formula of any new compound, the positive ion is always written first.

Ions sometimes change 'partners' when a chemical reaction takes place.



INVESTIGATION 7.6

Will it precipitate?

AIM: To investigate precipitation reactions

You will need:

5 semi-micro test tubes and test-tube rack
a white tile
a black tile
safety glasses
dropping bottles of the following solutions: copper sulfate, sodium chloride, silver nitrate, cobalt chloride, sodium hydroxide and potassium iodide

CAUTION: Wear safety glasses.

- Place 10 drops of copper sulfate solution in each test tube.
- Add 10 drops of sodium chloride to the first test tube, 10 drops of silver nitrate to the second, and so on until each tube contains copper sulfate solution and one other solution. Hold a black or white tile behind the test tube if necessary to detect the presence of a precipitate.
- If there is a reaction, record your observations in a table.

- Tip the residues into a waste bottle. Wash out the test tubes thoroughly and this time place 10 drops of sodium chloride in each of the test tubes. Again add one of the other solutions to each of the test tubes (but not copper sulfate as this combination has already been tested). Record your observations in your table.
- Repeat until all possible pairs of solutions have been tested.

Discussion

1. Write word equations for each of the pairs that reacted to form a precipitate.
2. Use formulae to write equations for each of the pairs that reacted to form a precipitate.
3. You could have predicted which pairs of solutions would form a precipitate using the box of solubility rules on page 280. Check to see if the rules match your results.

7.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the term 'precipitate'.
2. Why don't all reactions between salts produce precipitates?
3. **Explain** how a reaction between colourless substances can produce a coloured precipitate.

Think

4. Are all precipitates insoluble in water? **Explain**.
5. Write an equation for the reaction that occurs when the salt, copper sulfate, dissolves in water.
6. **Identify** which two of the following compounds will be soluble in water.
   (a) $NaNO_3$
   (b) KI
   (c) PbI_2
   (d) $Zn(OH)_2$
7. **Identify** which of the following compounds will be insoluble in water.
   (a) $CuCO_3$
   (b) AgI
   (c) NaCl
   (d) $Mg(OH)_2$
8. Write down the possible combinations of ions when the following solutions are mixed together:
   (a) sodium chloride and copper sulfate
   (b) sodium hydroxide and copper sulfate
   (c) lead nitrate and sodium hydroxide
   (d) potassium iodide and sodium carbonate.
9. For each of the reactions listed in question 8, **identify** the precipitate that would form. If you believe that no precipitate would form, write 'no precipitate'.

Investigate

10. To find out more about precipitation and other reactions use the **Introduction to reactions** weblink in the Resources tab.

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Explore more with this weblink: Introduction to reactions

Complete this digital doc: Worksheet 7.5: Precipitation (doc-12777)

7.8 Metal displacement reactions

7.8.1 The activity series

The word *displace* means 'to push out of place', and that pretty much sums up displacement reactions. Displacement reactions occur where one metal pushes another out of a compound and takes its place.

For example, when a strip of magnesium metal is added to lead sulfate, the magnesium pushes the lead out of the sulfate compound and joins with it. As a result, the products of the reaction are magnesium sulfate and lead (which precipitates out). The equation for this reaction is:

$$\mathbf{Mg(s) + PbSO_4(aq) \rightarrow MgSO_4(aq) + Pb(s)}$$

Some metals are more likely to take part in displacement reactions than others. Gold and silver for example, very rarely take part in displacement reactions.

A measure of how likely a particular metal is to take part in a displacement reaction is its **reactivity**.

Some metal elements, like potassium, lithium and sodium, are so reactive that they have to be stored under oil to stop them from reacting with substances in the air. The more reactive metals are never found in a pure form naturally — they are always found in the form of a metal compound. Unreactive metals such as gold, on the other hand, are most likely found as a pure metal nugget or seam.

The activity series places the metallic elements in decreasing order of reactivity. This series is shown below.

In order for a metal to displace another in a compound, it must be higher on the activity series. So, if we put magnesium metal in a copper sulfate solution, the magnesium will displace the copper to form magnesium sulfate. However, if we were to put a strip of copper into a magnesium sulfate solution, no displacement would occur — they'd pretty much just sit there and look at each other!

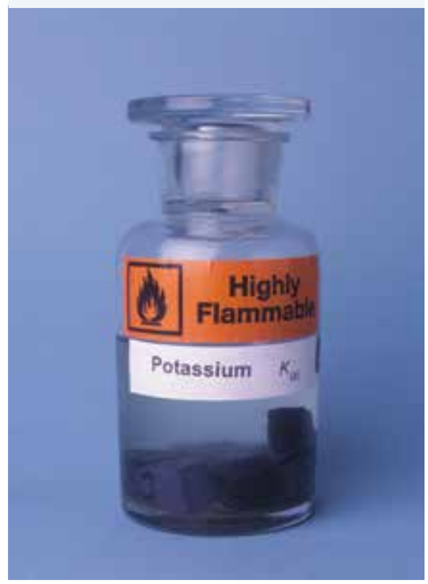
In order for a metal to react with acid and release hydrogen gas, the metal must be before hydrogen in the activity series.

The reactivity of metals can be investigated by observing the reactions of metals with acids. When a metal reacts with hydrochloric acid, it reacts according to the equation:

metal + hydrochloric acid → salt + hydrogen gas

In these reactions, electrons are transferred away from the metal atoms to the hydrogen in the acid, forming positive metal ions and hydrogen gas. These are referred to as **redox reactions** (we will look at what a redox reaction is in more depth in the next subtopic). As the metal has displaced the hydrogen from the acid, these reactions are also displacement reactions.

Lithium, sodium and potassium are stored under oil so that they can't react with the air. These substances react quickly and explosively when in contact with water in the air.



Li	K	Na	Ca	Mg	Al	Mn	Cr	Zn	Fe	Ni	Sn	Pb	H	Cu	Hg	Ag	Au	Pt

Decreasing reactivity →

HOW ABOUT THAT!

Gold is so unreactive that it can be placed in concentrated hydrochloric, nitric or sulfuric acid without effect. No single acid is able to dissolve gold. However, there is one substance that will. Alchemists called it *aqua regia* ('*royal water*') and it is made up from a mixture of concentrated hydrochloric and nitric acid. It can also dissolve platinum, yet the metals osmium, tantalum and iridium remain unaffected by it!

INVESTIGATION 7.7

Measuring the reactivity of metals

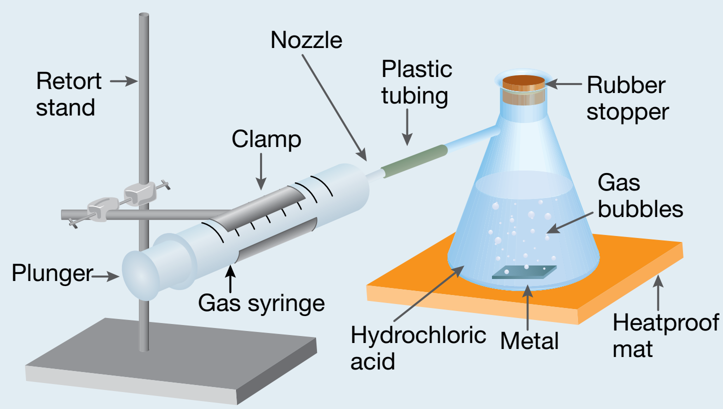
AIM: To construct a metal activity series

You will need:

safety glasses and laboratory coat
steel wool
1 cm × 4 cm pieces (or equivalent amount) of copper, zinc, aluminium, iron and magnesium
gas syringe
retort stand, bosshead and clamp
heatproof mat
distilled water
1 cm diameter × 4 cm long piece of plastic tubing
1 M hydrochloric acid
100 mL measuring cylinder
250 mL side-arm conical flask
rubber stopper to fit conical flask
stopwatch or clock with a second hand

CAUTION: Wear safety glasses.

- Before starting this investigation, read all of the instructions and construct a table suitable for recording your measurements.
- Use the steel wool to polish each of the samples of metal.
- Mount the gas syringe in the clamp as shown in the diagram right. Your teacher will tell you if the syringe needs to be lubricated. Push the plunger in fully and attach the plastic tubing to the nozzle.
- Carefully measure out 50 mL of hydrochloric acid and pour it into the conical flask.



- Connect the free end of the plastic tubing onto the arm of the flask.
- Prepare to start timing. Carefully add one of the pieces of metal to the flask and quickly seal it with the rubber stopper. Start timing as soon as the metal is placed in the flask.
- Record (in your table) the volume of gas in the syringe every 30 seconds until gas is no longer produced, the syringe is full or 10 minutes has passed, whichever occurs first.
- Repeat this procedure with the other metal samples. Rinse the conical flask with distilled water each time before repeating the procedure.
- When you have completed your measurements, plot a graph of the results on a single set of axes. Your graph should show how the volume of gas for each sample changes with time. That is, plot volume of gas on the vertical axis and time on the horizontal axis.

Discussion

1. Use your graph to list the five metal elements in order of reactivity.
2. Write a word equation for the reaction of each of the metal elements with the acid. If no reaction occurred, write ‘no reaction’.
3. Some of the variables in this investigation were not well controlled. List them and explain how the lack of control may have affected your results.

7.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** why pure gold is more likely to be found in the ground than pure sodium.
2. **Describe** the activity series of metals.
3. **Identify** the gas that is always formed when a metal reacts with an acid.

Think

4. Balance these chemical equations that describe the reaction between acids and metals
   (a) $\mathbf{Zn(s) + HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)}$
   (b) $\mathbf{Na(s) + HCl(aq) \rightarrow NaCl(aq) + H_2(g)}$
5. You have a choice of making a piece of jewellery from either zinc or nickel. Which metal would you choose? Justify your choice.
6. The elements gold, silver, copper and iron were all discovered more than 6000 years ago. Yet, the elements potassium, sodium and calcium were not discovered until 1808. Suggest a reason for this.

Investigate

7. Find out at least four different ways of treating iron (other than mixing it with other elements to make an alloy) to prevent or reduce its corrosion.
8. Design and carry out an experiment that investigates the reactivity of alloys, such as stainless steel and brass. Compare these results with those obtained for the metal elements. Present the findings of your investigation as a poster to display in your classroom.

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Complete this digital doc: Worksheet 7.6: Metal displacement (doc-12778)

7.9 Reactions everywhere!

7.9.1 Explaining reactions — redox

In a world where countless chemical reactions take place, it is helpful to classify the reactions. They can be classified according to whether they release or absorb energy, and can also be grouped together according to the nature of the reactants, the nature of the products, the way in which charged particles in atoms rearrange themselves or even the number of reactants. Because there are different ways of classifying chemical reactions, any one reaction can fall into several different groups.

In many chemical reactions, electrons are either completely or partially moved from one atom, ion or molecule to another. This process is known as **electron transfer**. Chemical reactions that involve electron transfer are called redox reactions. Redox reactions are extremely important in industry and in our everyday lives.

A redox reaction is really two reactions occurring simultaneously. In the electron transfer process, one reactant loses electrons and another gains electrons. Loss of electrons is known as **oxidation**. Gain of electrons is called **reduction**. Oxidation and reduction always occur together, thus the two words are combined to form the word redox, which is used to describe reactions where electrons are transferred.

The mnemonic OIL RIG may help you to remember these processes: Oxidation Is Loss, Reduction Is Gain.

The corrosion, displacement, combustion and combination reactions described on next page are examples of redox reactions. Oxidation and reduction can be clearly seen in the reaction that occurs when zinc corrodes (see next page).

Corrosion reactions

Corrosion is a chemical reaction that occurs between a metal and substances occurring in the air or water around it that causes the metal to be eaten away over time. The tarnish that appears on silver cutlery, the milky green verdigris that builds up on copper and bronze statues and the dull grey layer that coats bare aluminium window frames are all examples of corrosion, as is the rusting of iron.

Corrosion of zinc

If you look at a sheet of galvanised iron, you will notice that it does not have a shiny metallic surface. Galvanised iron has been coated with a layer of zinc metal. The zinc prevents the iron underneath from reacting with the oxygen and water in the air and rusting. Instead, it is the zinc that corrodes, reacting with oxygen to form a dull layer of zinc oxide on the surface of the metal. The chemical equation for this reaction is:

$$2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$$

Now, let's consider this from the redox point of view. When the zinc corrodes, electrons are transferred from the zinc atoms to the oxygen molecules, causing the formation of positive zinc ions and negative oxide ions. These oppositely charged ions attract and bond together to form the ionic compound zinc oxide:

$$\textbf{2 zinc atoms + 1 oxygen molecule} \rightarrow 2Zn^{2+} + 2O^{2-}$$
$$2Zn^{2+} + O_2 \rightarrow + 2ZnO$$

In this reaction, zinc atoms lose electrons, thus zinc is oxidised. Oxygen molecules gain electrons, thus oxygen is reduced. Remember that oxidation and reduction always occur together.

Combustion reactions

Combustion reactions are those in which a substance reacts with oxygen and heat is released. Examples of combustion reactions include the burning of petrol in a motorcycle engine, wax vapour in a candle flame and natural gas in a kitchen stove. In each of these cases **hydrocarbons** (compounds containing only the elements carbon and hydrogen) combine with oxygen in the air to form carbon dioxide gas and water vapour.

The rusting of this shed is an example of corrosion.

Combustion of methane

The chemical equation for the burning of methane is:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

methane + oxygen → carbon dioxide + water

In this redox reaction, electron transfer is not complete. The reactants are molecules and the products are also molecules. In each molecule, electrons are shared by the atoms. However, the oxygen atoms in the products attract the electrons more strongly than the carbon and hydrogen atoms. Therefore, the shared electrons spend more time close to the oxygen atoms. The electrons have been partially transferred to the oxygen atom. Thus, oxygen is reduced and the carbon in methane is oxidised.

Combination reactions

A **combination reaction** (also known as a **synthesis reaction**) is one in which two reactants produce a single product usually accompanied by a release of energy in the form of heat and/or light. One spectacular example of this type of reaction is that between magnesium and oxygen. As the magnesium metal burns in air it produces a brilliant white light. The equation for this combination reaction is:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

magnesium + oxygen → magnesium oxide

In this reaction, electrons are transferred from the atoms in the magnesium metal to the oxygen atoms in the oxygen molecule. This forms positive metal ions and negative oxide ions. These ions are attracted to each other due to their opposite charges and form the white, ionic, solid magnesium oxide. Magnesium, which loses electrons, is oxidised, and oxygen is reduced.

$$2Mg(s) + O_2(g) \rightarrow 2Mg^{2+} + 2O^{2-} \rightarrow 2MgO(s)$$

Decomposition reactions

In decomposition reactions one single compound breaks down into two or more simpler chemicals. This is pretty much the opposite of a combination reaction. An example of this is the decomposition of zinc carbonate which is represented by the equation:

$$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$$

zinc carbonate → zinc oxide + carbon dioxide

INVESTIGATION 7.8

Decomposing powder

AIM: To carry out a quantitative investigation of a decomposition reaction

You will need:

laboratory coat and safety glasses
zinc carbonate powder
spatula
Bunsen burner, heatproof mat and matches
large pyrex test tube and test-tube rack
test-tube holder
an electronic balance
marking pen
stereo microscope
Petri dish

CAUTION: Wear safety glasses and laboratory coat.

- Place two spatulas of zinc carbonate powder in the test tube. Weigh the test tube and record the mass.
- Mark the level of the powder in the test tube with the marking pen.
- Heat the test tube gently in a blue Bunsen burner flame for 5 to 10 minutes.

CAUTION: Make sure the test tube is not pointing at anyone.

- While heating the test tube, hold a lit match at the mouth of the tube. Record your observations.
- Allow the test tube to cool down. Note any change in the level of powder and then reweigh the test tube. Record the mass.
- Place small amounts of zinc carbonate and the powder from the test tube in the Petri dish. Examine them using a stereo microscope. Record your observations.

Discussion

1. Which gas was given off during the reaction?
2. Explain any change that occurred in the mass.
3. Write word and formula equations for the reaction.

Displacement reactions

A displacement reaction occurs when a more reactive metal displaces a less reactive metal and takes its place in a compound. As we saw in the previous subtopic, silver has a low reactivity and is easily ‘pushed out’ of compounds by more reactive metals. When copper reacts with silver nitrate, the more reactive copper displaces the silver atom to form copper nitrate, leaving the silver to precipitate out as a solid:

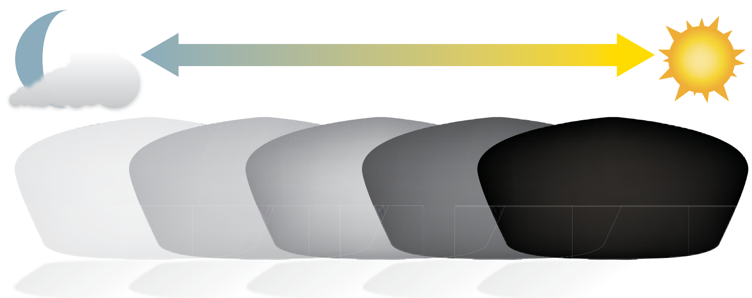
Cu(s) + 2AgNO3(aq) → 2Ag(s) + Cu(NO3)2(aq)

copper + silver nitrate → silver + copper nitrate

In this reaction, electrons are transferred from the copper atoms to the silver ions. Silver ions (Ag^+) in the solution gain electrons to form atoms of solid silver. Thus, silver ions are reduced. Copper atoms ($Cu(s)$) lose electrons, forming copper ions (Cu^{2+} (aq)), which dissolve into a solution. The formation of copper ions changes the colour of the solution from colourles$_s$ to blue. The copper atoms are oxidised. The nitrate ion is not involved in the electron transfer. Ions that are not involved in ion transfer are referred to as **spectator ions**.

7.9.2 Redox in the light and the shade

Photochromic lenses darken in the presence of bright light then become clear when the ambient light becomes dim because of a series of redox reactions.



People who wear glasses often don't want to bother with swapping over to sunglasses when they go outside. **Photochromic** glasses solve the problem by darkening as the wearer moves from indoors into bright sunshine. They lighten again when the wearer moves back into an area of low light. Plastic photochromic glasses use organic material which darkens the lenses when exposed to ultraviolet light. Glass photochromic glasses work due to the presence of silver chloride (AgCl) crystals in the glass. When a wearer is in the sunshine, ultraviolet light is absorbed by the silver chloride crystals and a redox reaction occurs. Electrons are transferred from the chloride ion to the silver ion according to the equation:

$$\mathbf{Ag^+ \text{ (ion)} + Cl^- \text{ (ion)} \rightarrow Ag \text{ (atom)} + Cl \text{ (atom)}}$$

Silver particles then form in the glass, darkening the lens so that visible light is absorbed and reflected.

The fading of the dark glass is more complicated. The chlorine atoms are very reactive. To stop them reacting with the silver atoms and reversing the process too quickly, singly charged copper ions are dissolved in the molten glass during the manufacturing process. These ions react with the chlorine atoms to form chloride ions and doubly charged copper ions in the reaction:

$$\mathbf{Cu^+ + Cl \rightarrow Cu^{2+} + Cl^-}$$

When the glasses are no longer in the sunlight, the doubly charged copper ions accept an electron from the silver atom. The silver ion re-forms and the dark lens becomes light again:

$$\mathbf{Cu^{2+} + Ag \rightarrow Cu^+ + Ag^+}$$

7.9.3 Reactions with a zap!

The chemical reactions that produce electrical energy in electric cells (more commonly known as batteries) are redox reactions. In electric cells, electrons are transferred from one reactant to another through the wires that make up the electric circuit. This is very useful because the moving electrons can provide the energy to operate our appliances. Thus, chemical energy from the redox reaction is converted to electrical energy. The reactants in the cells are not in direct contact with each other. In an ordinary carbon battery or dry cell, the reactants are separated by a paste that allows the movement of electric charge. The electrons flow from one reactant at the negative electrode, through the electric circuit to the other reactant at the positive electrode. Chemical products are formed at both electrodes.

7.9 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Construct** a table similar to the one at the right and use it to summarise each of the groups of reactions discussed in this subtopic. List one example of a reaction for each group.

Reaction type	Description	Example

2. **Recall** what all redox reactions have in common.
3. **Define** the term ‘oxidation’.
4. **Define** the term ‘reduction’.
5. **Explain** where the word redox came from.
6. Consider the reaction:

$$2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$$

   (a) **Identify** which reactant the electrons are being transferred from.
   (b) **Identify** which reactant the electrons are transferred to.
7. Give an example of a redox reaction where the electron transfer is not complete.

Think

Refer to the tables of electrovalencies in topic 5 and the table of neutralisation reactions in this topic to answer question 8.

8. Write a balanced equation using formulae for the following reactions:
   (a) **copper metal + zinc sulfate solution → zinc metal + copper sulphate solution**
   (b) **sodium metal + oxygen gas → solid sodium oxide**
   (c) **carbon monoxide gas + oxygen gas → carbon dioxide gas**
   (d) hydrogen peroxide (H_2O_2) solution decomposes to form hydrogen gas and oxygen gas.
9. **Identify** the type of each of the reactions inquestion 8 (remember, a reaction may be more than one type!).
10. **Explain** how it can be said that the reaction between magnesium and oxygen is four reactions in one: ‘a combustion reaction’, ‘a combination reaction’, ‘a redox reaction’ and ‘an exothermic reaction’.

Investigate

11. Find out what a Daniell cell is and how redox can be applied to the way in which it produces electric current
12. Use the **Chemical reactions** weblinks in the Resources tab to learn more about the different types of chemical reactions.

learnON RESOURCES — ONLINE ONLY

Try out this interactivity: Time out ‘Reactions’ (int-0759)

Explore more with this weblink: Chemical reactions

Complete this digital doc: Worksheet 7.7: Corrosion and combustion (doc-12779)

7.10 Seeing the light!

Science as a human endeavour

It’s a scene that you always see in crime shows on the TV. The forensic scientists spray a mysterious chemical over a seemingly clean carpet, they turn out the lights and suddenly, you see a glowing spatter pattern and drag marks appearing. A footprint is outlined where it stepped through the blood that has since been cleaned away. This is the scene of a crime! So what is this mysterious glowing chemical? Why doesn’t it glow while it’s being sprayed on the carpet?

7.10.1 Glowing in the dark

While combustion reactions such as the burning of wood may produce light as a result of the heat produced, some reactions release light with very little heat being produced.

Chemiluminescence is light that is produced as a result of a chemical reaction. This light is called 'cold light' because very little heat is produced during these reactions. Luminol and glow sticks both produce chemiluminescence as the result of specific reactions.

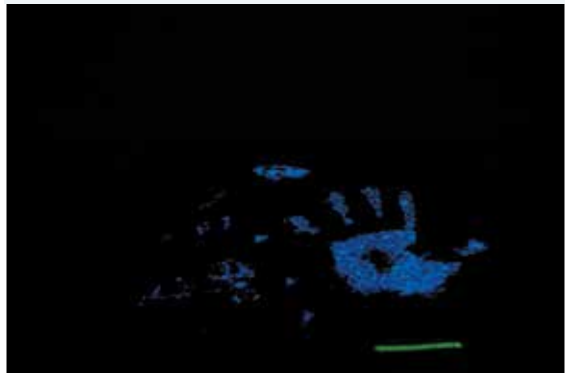
Crime scene chemicals

Luminol is a chemical that reacts with hydrogen peroxide to produce aminophthalate and light. This reaction is normally slow and the light produced is quite weak. However, some substances such as the iron found in blood act as **catalysts** for the reaction.

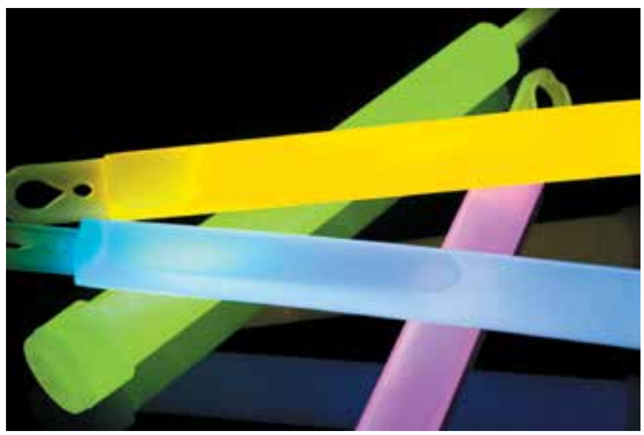
$$\textbf{luminol + hydrogen peroxide} \xrightarrow{\textbf{iron}} \textbf{aminophthalate + light}$$

Crime scene technicians use a mixture of luminol and hydrogen peroxide to detect traces of blood even if none is visible to the naked eye. The area is sprayed evenly with the mixture and, where even tiny amounts of blood may be present, the iron in the blood causes the reaction between the luminol and the hydrogen peroxide to speed up. The reaction produces a blue glow which can be seen if the room is made dark. This glow lasts about 30 to 40 seconds allowing the blood patterns to be photographed and recorded for later comparison with the lit crime scene.

Revealed in light — the scene of the crime



Glow sticks



Glow sticks are a big party favourite and they also rely on chemiluminescence for their light. A glow stick is made up of two tubes, one inside the other. The small inner tube is made of glass and contains a solution of hydrogen peroxide while the larger flexible outer tube holds a chemical called phenyl oxalate ester and a coloured fluorescent dye.

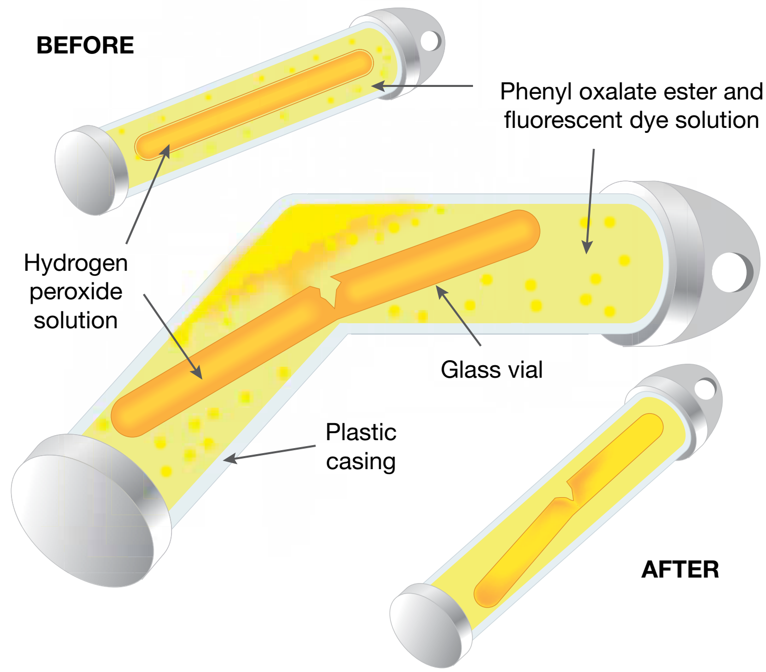
When you bend the glow stick, the inner tube is cracked open, allowing the hydrogen peroxide to react with the ester. This reaction produces a chemical called phenol, and carbon dioxide and energy which stimulates the dye to produce light without producing heat. The colour of the light produced depends upon the colour of the fluorescent dye present. Eventually, when all of the reactants are used up, the glow stick stops glowing.

That natural glow

Bioluminescence is the light produced by living organisms such as fireflies, glow worms and many deep ocean creatures. This light is caused by chemical reactions within the body of the organism itself, so bioluminescence can be thought of as a form of chemiluminescence.

The key reaction in bioluminescence occurs between a natural pigment called **luciferin** and oxygen. Another chemical, **luciferase**, acts as a catalyst in the reaction, allowing light to be produced from the organism's body. Different organisms produce different colours of bioluminescence according to the type of luciferin that they have.

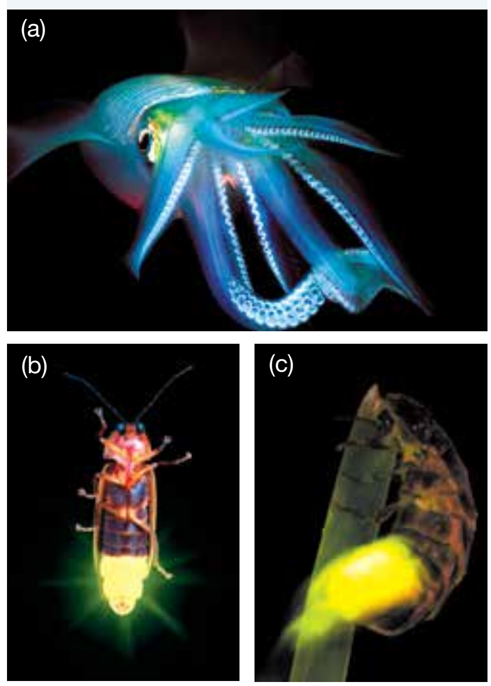
How a glow stick works



Mimicking bioluminescence

The production of cool light by fireflies has been used as a model for the development of chemiluminescent materials. Although the production of light by chemiluminescence has been possible for some time, commercial applications were often not developed because the reactions were relatively inefficient. The firefly is able to produce light very efficiently by the chemical reactions in the cells of its abdomen. However, in recent years chemical research has uncovered new chemiluminescent reactions and more efficient reactions have been developed. This has enabled the commercial production of chemiluminescent items and the use of chemiluminescence techniques in scientific research.

Many different creatures exhibit bioluminescence including (a) squid (b) fireflies and (c) glow worms.



Using chemiluminescence and bioluminescence

The reactions that occur in chemiluminescence and bioluminescence have been adapted for use in scientific research, medicine, ecology, hygiene and food quality control.

Bioluminescence is used when testing for tuberculosis to determine the most suitable antibiotic to be given to the patient. Scientists have used gene transfer technology to insert the firefly's gene for making luciferase enzymes into bacteria from the tuberculosis patient. These bioluminescent bacteria are then tested for their resistance to different antibiotics.

The effectiveness of the antibiotics can be easily determined by the amount of bioluminescence remaining.

Bioluminescent bacteria have also been used to test for mercury pollution in water. No doubt in the future many more uses will be found for chemiluminescence and bioluminescence.

7.10 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What is chemiluminescence?
2. Give two examples of chemiluminescent reactions.
3. What are the (a) reactants (b) products in the reaction in a glow stick?
4. How does chemiluminescence differ from bioluminescence?
5. **Describe** at least two ways in which chemiluminescence differs from the luminescence provided by a light bulb.
6. Draw a diagram to explain how light is produced in a chemiluminescent light stick.

Think

7. Most of the organisms found in the deep ocean display bioluminescence. Why do you think this is the case?
8. When magnesium burns in oxygen, it produces an intense white light. Is this an example of chemiluminescence? **Explain** your answer.
9. Glow sticks aren't just good for producing party light. Give two other occasions in which glow sticks are put to use.

Investigate

10. One of the chemicals involved in bioluminescence is called luciferase. Find out how it got this name.
11. In crime shows, you sometimes see blood and other body fluid traces being detected by technicians shining an ultraviolet light (or 'black' light) on a surface. **Investigate** why this works and what its limitations are.
12. Use the internet and other sources to further **investigate** luminol and answer the following questions.
    (a) **Identify** the chemicals that luminol is made from.
    (b) **Identify** other substances, apart from blood, that will make luminol glow.

7.11 Taking care with chemicals

7.11.1 Harmful chemicals

Many of the chemicals used in industry, medicine, schools, universities and homes can be hazardous to your health. The hazards come about because these chemicals can react with parts of your body — inside or out. Apart from the dangers to your own health, chemicals can, as a result of their properties or their reactions with common substances such as water and air, cause great damage to property and the environment.

Laws exist, at both national and state level, to ensure that people using harmful chemicals are informed about how to handle and use them safely. For this purpose, harmful chemicals are placed within one or both of the groups known as **dangerous goods** or **hazardous substances**.

7.11.2 Dangerous goods

Chemicals in the dangerous goods group are those that could be dangerous to people, property or the environment. Most dangerous goods are grouped into one of nine classes, according to the greatest immediate risk they present. Some of the classes are divided into subclasses. Dangerous goods must be identified with the appropriate dangerous goods sign on their labels. The table on the next page lists nine of the classes and subclasses, along with their respective label signs. These signs must, by law, be prominently placed and clearly visible. Their design also includes a symbol for the type of hazard they present.

Outside these nine classes, there are two other groups of dangerous goods:

1. goods too dangerous to be transported (GTDTBT)
2. combustible liquids (C1), which includes liquids that are not as easily ignited as flammable liquids, but which will ignite at temperatures below their boiling point.

Classes and subclasses of dangerous goods

Class	Description	Sign
Class 1	Explosive substances or articles used to produce explosions	
Class 2.1	Flammable gases: gases that ignite in air if in contact with a source of ignition such as a spark or flame	
Class 2.2	Non-flammable, non-toxic gases: these gases may cause suffocation	
Class 2.3	Toxic gases: gases likely to cause death, serious illness or injury if inhaled	
Class 3	Flammable liquids: liquids with vapours that can ignite on contact with air at temperatures below 60°C	
Class 4.1	Flammable solids: solids that are easily ignited by a source of ignition such as a spark or flame	

(*Continued*)

Class	Description	Sign
Class 4.2	Substances liable to spontaneous combustion: solids that can ignite without an external source of ignition	
Class 4.3	Substances that emit flammable or toxic gases on contact with water	
Class 5.1	Oxidising agents: substances that may contribute to the combustion of other substances, increasing the risk of fire	
Class 5.2	Organic peroxides: substances that undergo exothermic decomposition reactions	
Class 6.1	Toxic substances: chemicals likely to cause death, serious illness or injury if swallowed, inhaled or brought into contact with skin	
Class 6.2	Infectious substances: substances containing micro-organisms likely to cause diseases in humans or animals	
Class 7	Radioactive material	

Class	Description	Sign
Class 8	Corrosive substances: substances that corrode metals or cause injury by reacting on contact with living tissue	
Class 9	Miscellaneous dangerous goods and articles: dangerous substances and objects that do not belong to the other classes	

7.11.3 Hazardous substances

Chemicals in the hazardous substances group are those that have an effect on human health. The effect may be immediate, such as poisoning and burning, or long term, such as liver disease or cancer. Hazardous substances can enter the body in a number of ways. They can be inhaled, absorbed through the skin, ingested (swallowed) or injected.

Hazardous substances are identified on their labels by a 'signal word' providing a warning about the substance, or the word 'hazardous' printed in red. 'Signal words' include 'dangerous poison', 'poison', 'warning' and 'caution'. Labels of hazardous substances also include:

- information about the risks of the substance
- directions for use
- safety information
- first aid instructions and emergency procedures.

If the substance is also in the dangerous goods group, the label will also include the appropriate diamond sign showing its class.

Keeping you informed

All employers are required by law to make sure that their employees are fully informed about the chemicals in the workplace that are classified as dangerous goods and/or hazardous substances.

A list of such chemicals stored or used in the workplace must be kept, along with a copy of the chemical's **MSDS (material safety data sheet)**. Chemical suppliers are required to provide a MSDS for each of the hazardous substances or dangerous goods that they supply. In turn, employers are required to make the MSDS accessible to employees who are exposed to the chemicals.

A MSDS is likely to consist of several A4 pages and many can be downloaded directly from the internet. The information on a MSDS should include:

- the ingredients of the product
- the date of issue — an up-to-date MSDS should be no more than 5 years old
- information about health hazards and first aid instructions
- precautions that need to be taken when using the product
- information about storage and safe handling of the product.

7.11.4 Assessing risk

A risk assessment identifies the potential hazards of an experiment and gives protective measures to minimise the risk. Before any experiment involving chemicals is conducted in your school laboratory, a risk assessment is carried out. The form of a risk assessment varies from school to school, but will always contain:

- a summary of the experiment
- a list of the risks and safety precautions for each chemical
- information about whether the chemical is classified as a hazardous substance or dangerous good
- a list of protective measures to be taken. These might include the use of a fume hood and/or the wearing of safety glasses or other protective items.
- first aid information.

Most of the information used in a risk assessment is obtained from the MSDS for each of the chemicals used. The date on the MSDS used for each chemical must be stated to ensure that the risk assessment is up to date.

Risk assessment sheets in schools are usually completed and signed by a qualified science teacher or laboratory technician. Your science teacher is required to carefully read the risk assessment sheet before allowing an experiment involving chemicals to commence.

7.11 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Describe** what the chemicals listed as dangerous goods have in common.
2. If a chemical in the dangerous goods group is explosive, toxic and corrosive, how is it decided to which class the chemical belongs?
3. **Recall** what the chemicals listed as hazardous substances have in common.
4. **Identify** four 'signal words' used on the labels of hazardous substances.
5. What is a MSDS and what should it include?
6. Where can employers obtain a MSDS for hazardous substances and dangerous goods?
7. Whose responsibility is it to make sure that people have access to an MSDS for each of the hazardous chemicals and dangerous goods that they store or use?

Think

8. **Describe** what characteristics chemicals listed as both dangerous goods and hazardous substances have in common.
9. **Distinguish** between flammable liquids (Dangerous goods, Class 3) and explosive liquids (Dangerous goods, Class 1).
10. **Explain** the difference between the purposes of a MSDS and a risk assessment sheet.
11. **Explain** why every chemical used in a laboratory (including water) should be considered to be a health hazard.

Investigate

12. Many chemical suppliers provide access to MSDSs online. Use the internet to search for a MSDS on hydrochloric acid and use it to answer the following questions.
    (a) **Identify** some alternative names for hydrochloric acid.
    (b) What are the health hazards of hydrochloric acid?
    (c) **Describe** the first aid treatment recommended if hydrochloric acid: (i) is ingested (swallowed) (ii) is inhaled (iii) makes contact with an eye (iv) makes contact with the skin.
    (d) **Summarise** the recommendations made for the storage of hydrochloric acid.

7.12 Project: ChemQuiz!

7.12.1 Scenario

You only have to have a glance at any page of your TV guide to see that Australians young and old love a good quiz show. Whether it's *Hot Seat, Jeopardy, Spit it Out* or *It's Academic*, programs with a quiz show format rate consistently well. While the idea of watching someone answer questions seems like an odd form of entertainment, psychologists theorise that their popularity arises from a combination of a desire to learn new information and a form of competition — after all, who hasn't watched a quiz show and yelled the answers at the screen? In recent educational studies, the use of quiz game formats as a teaching tool in the classroom is gaining support.

The Brain Mine is a company that specialises in educational resources for use in Science classrooms. On the basis of these educational studies of quiz games, they have decided that they would like to add a computer-based chemistry quiz show that teachers could purchase and run in their classrooms as a fun and effective way of improving student knowledge. As product developers at The Brain Mine, it is up to you and your team to make this happen! You and your team are going to develop *ChemQuiz*, a chemistry-based quiz show in which the class teacher will act as the show host, groups of students will be the contestants and the questions (which pop up on a computer screen so that the contestants can see them) are based on chemistry skills.

7.12.2 Your task

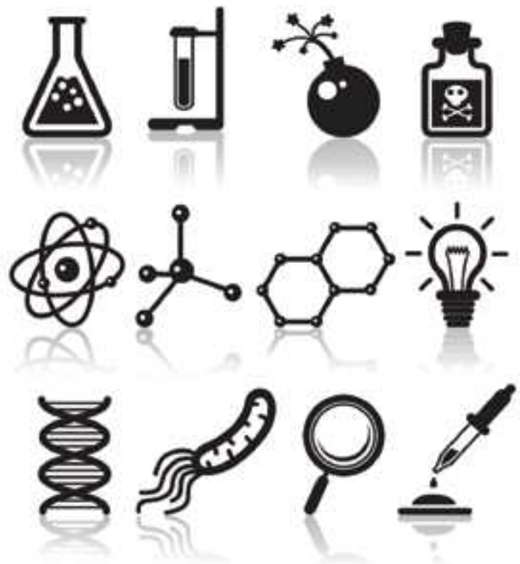
Using PowerPoint, you will create a series of question screens for a quiz show that should run for about ten minutes. For each question screen, the show host must be able to reveal the correct response after a contestant has given their answer. The question screens should be entertaining and eye-catching, and should also be easily readable by the contestants and the show host (who will read the questions out as they appear).

You will need to give a demonstration of your *ChemQuiz* show with one of your group acting as the show host (the role that would normally be taken by the teacher). The show host will need to explain the rules of the quiz show at the start. The contestants will be your fellow students (preferably not those in your group, who will already know the answers!).

7.12.3 Process

- You can complete this project individually or invite other members of your class to form a group.
- Start your research. Make notes of ideas that you can use when creating your quiz questions, such as interesting chemical facts, balancing equations, remembering chemical symbols and names, determining

the products of a chemical reaction and so on — remember that the audience and contestants for *Chem-Quiz* will be Year 9 or Year 10 students.
- Use your questions, answers and PowerPoint to create your *ChemQuiz* gameshow!



7.13 Review

7.13.1 Communicating chemistry

- write word equations to **describe** common reactions between chemicals **7.2**
- **distinguish** between reactants and products **7.2, 7.3**
- **define** the terms 'exothermic' and 'endothermic' with regard to reactions **7.4**
- write balanced chemical equations using chemical formulae to **describe** important chemical reactions between substances **7.3**
- **recall** the Law of Conservation of Mass and the Law of Constant Proportions **7.2**

7.13.2 Using chemicals

- **distinguish** between an acid and a base **7.5**
- **predict** the products that are formed as the result of neutralisation reactions **7.5**
- **describe** the role of chemical indicators **7.5**
- **recall** common uses of both acids and bases in everyday life **7.5**
- **define** the term 'chemical salt' **7.5, 7.6**
- **distinguish** between hazardous and dangerous chemicals **7.11**
- **recall** the purpose of a risk assessment and a MSDS **7.11**

7.13.3 Chemical reactions

- **describe** the reactants and the products in a variety of neutralisation, combustion, corrosion, precipitation, decomposition and metal displacement reactions **7.5, 7.6, 7.7, 7.8, 7.9**

- **distinguish** between combustion and corrosion 7.9
- **describe** what redox is and explain how the term can be applied to thechemical reactions already studied 7.9
- **explain** how the formation of a precipitate as a result of a chemical reaction may be predicted 7.7

7.13.4 Applications and uses of science

- **define** the terms 'chemiluminescence' and 'bioluminescence' and recall some of their uses 7.11

Individual pathways

ACTIVITY 7.1	ACTIVITY 7.2	ACTIVITY 7.3
Revising chemical reactions doc-10655	Investigating chemical reactions doc-10656	Investigating chemical reactions further doc-10657

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FOCUS ACTIVITY

Devise a presentation in the media of your choice to explain the chemical reactions that occur in one day of your daily life.
Access more details about focus activities for this topic in the Resources tab (doc-10654).

assesson

7.13 Review 1: Looking back

1. French chemist Antoine-Laurent Lavoisier provided evidence that led to the development of the Law of Conservation of Mass and the Law of Constant Proportions.
   (a) Use the Law of Conservation of Mass to **explain** why it is incorrect to say that when a candle burns it disappears.
   (b) **Recall** the Law of Constant Proportions.
2. In an experiment to test the effect of the amount of liver on the breakdown of hydrogen peroxide, the results shown at right were obtained.

Mass of liver (g)	Volume of oxygen released (cm^3)
0.5	2.5
1.0	5.1
2.0	9.8
2.5	11.5

   (a) Write a word equation for the reaction occurring in this experiment.
   (b) Use formulae to write an equation for this chemical reaction.
   (c) Graph these results on graph paper.
   (d) **Describe** what the graph shows about the effect of the liver on the rate of this reaction.
3. When an aqueous solution of barium hydroxide reacts with an aqueous solution of ammonium hydroxide, the temperature of the products becomes low enough to freeze water.
   (a) **Define** the term 'aqueous solution'.
   (b) Is this an example of an exothermic or endothermic chemical reaction? **Explain** your answer.
   (c) **Deduce** where the energy transferred to or from the reactants goes.
4. Write balanced equations using formulae for the following reactions.
   (a) **aluminium metal + oxygen gas → solid aluminium oxide**
   (b) **potassium metal + oxygen gas → solid potassium oxide**
   (c) **solid carbon + oxygen gas → carbon dioxide gas**

(d) **solid copper carbonate → solid copper oxide + carbon dioxide gas**

(e) **iron metal + sulfur powder (S8) → solid iron sulfide (FeS_2)**

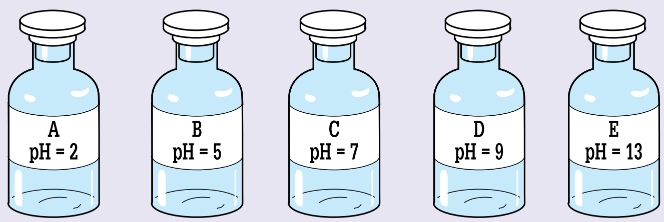
(f) **copper sulphate solution + zinc metal → copper metal + copper sulphate solution**

(g) **copper(II) sulfate solution + sodium hydroxide solution → solid copper(II) hydroxide + sodium sulfate solution**

(h) **solid magnesium hydroxide + hydrochloric acid → magnesium chloride + water**

5. The two reactants in the chemical reaction taking place in the test tube shown at right are aqueous solutions. There is enough evidence in the photograph to identify the type of chemical reaction taking place.
   (a) **Identify** what type of chemical reaction this is.
   (b) **Explain** what evidence in the photograph identifies the type of reaction.

6. **Identify** the reaction type (displacement, decomposition, precipitation, combustion or neutralisation) for each of the reactions in question 5.
7. Which of the reactions in question 5 are redox reactions?
8. Many chemicals are classified as dangerous goods and/or hazardous substances.
   (a) **Describe** the differences between these two categories of chemicals.
   (b) **Recall** what these two categories of chemicals have in common.
9. What is a MSDS and what is it used for?
10. **Explain** why you are more likely to find pure gold than pure copper in the ground.
11. **Predict** the salts that would result from the neutralisation reaction between:
    (a) magnesium oxide and hydrochloric acid
    (b) copper(II) oxide and sulfuric acid
    (c) sodium hydroxide and acetic acid
    (d) sodium oxide and nitric acid.
12. The liquids in the bottles shown at right are labelled with their pH.
    Identify which of the bottles is most likely to contain:
    (a) distilled water
    (b) a strong acid
    (c) a strong base
    (d) vinegar
    (e) bathroom surface cleaner.



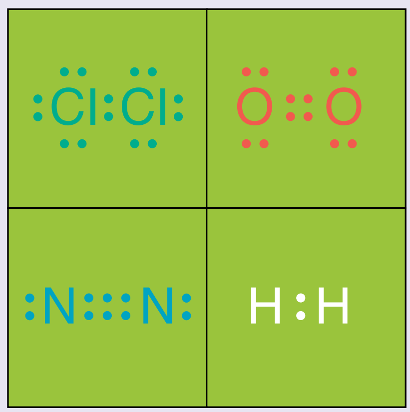
13. An experiment was carried out to measure how long it took for equivalent amounts of different metals to dissolve in 100 mL of hydrochloric acid. The results obtained are shown at right
    Unfortunately, the person recording the data on the computer accidentally changed the order of the metals recorded in the table. Using the known activity series table, redraw the table, redraw the table so that the correct metal is matched with the correct time.

Metal	Time taken for the metal to dissolve (min)
Iron	1.0
Magnesium	3.0
Tin	2.5
Aluminium	3.5
Nickel	2.0
Zinc	1.5

14. Early scientists mixed dilute hydrochloric acid with some calcium carbonate in a beaker and carefully weighed the beaker and its contents. After the bubbling had stopped, they discovered that there was a drop in mass. They used this experiment to state that the Law of Conservation of Mass was not true. Do you agree or disagree with the statement? **Explain**.
15. Currently, we use chemical equations to describe chemical reactions. How else could you describe a chemical reaction? Use an example to **explain** your new method.

Test yourself

1. What is the only reliable evidence indicating that a chemical reaction has taken place?
   (a) change in temperature
   (b) A change in state
   (c) Formation of a new substance
   (d) Disappearance of one or more reactants **(1 mark)**
   (e) Which of the following are products of the reaction between silver nitrate and sodium chloride?
   (f) Silver nitrate and sodium chloride
   (g) Nitrogen chloride and silver sodium
   (h) Do not react so there will be no products
   (i) Silver chloride and sodium nitrate **(1 mark)**
2. Which of the following are products of the reaction between silver nitrate and sodium chloride?
   (a) Silver nitrate and sodium chloride
   (b) Nitrogen chloride and silver sodium
   (c) Do not react so there will be no products
   (d) Silver chloride and sodium nitrate **(1 mark)**
3. The most reactive metal in the activity series is
   (a) lithium.
   (b) potassium.
   (c) platinum.
   (d) iron. **(1 mark)**
4. Which of the following is a balanced equation?
   (a) $\mathbf{Na + 2Cl \rightarrow 2NaCl}$
   (b) $\mathbf{MgO + 2HCl \rightarrow MgCl + H_2}$
   (c) $\mathbf{MgO + 2HCl \rightarrow MgCl_2 + H_2O}$
   (d) $\mathbf{2Na + Cl \rightarrow 2NaCl}$ **(1 mark)**
5. The electron dot diagrams for chlorine gas, hydrogen gas and oxygen gas are shown at right. The number of electrons in the outer shells of the elements that form these gases are 7, 1 and 6 respectively.
   (a) Draw electron dot diagrams for
      (i) hydrochloric acid (HCl)
      (ii) water (H_2O)
      (iii) carbon tetrachloride (CCl_4)
      (iv) carbon dioxide (CO_2).
   (b) Look at the electron dot diagram for nitrogen.
      (i) **Identify** how many electrons it has in its outer shell.
      (ii) Draw an electron dot diagram for ammonia (NH_3). **(4 marks)**



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Complete this digital doc: Worksheet 7.8: Chemical reactions puzzle (doc-12780)

Complete this digital doc: Worksheet 7.9: Chemical reactions summary (doc-12781)

TOPIC 8
The dynamic Earth

8.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

8.1.1 Why learn this?

The Earth seems fairly solid beneath our feet but, in fact, it is undergoing change all the time. Some of this change – such as the movement of the continents or the growth of mountain ranges – occurs very slowly over hundreds, thousands or even millions of years. At other times, the cataclysmic shock of earthquakes, volcanic eruptions and even land slips can drastically change the face of the Earth in a very short period of time.

A volcanic eruption can be both awe inspiring and deadly.

LEARNING SEQUENCE

assesson

What am I?

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Read the following descriptions and see if you can identify what is being described in each case.

1. I am an Australian monolith that millions of visitors from all over the world come to see every year. I was formed over the last 600 million years and I am composed of sandstone. I am over 3.5 kilometres long and it would take you about 2 hours to walk all the way around me.
2. I am a mountain made from the remains of the central vent of a massive shield volcano that last erupted about 23 million years ago. I was given my European name in 1770 by James Cook, who spotted me after he had passed dangerous reefs off the coast of what is now Fingal Head. However, the Bundjalung people called me Wollumbin.
3. I am an island country that is seismically active. I have volcanoes, high mountains and geothermal regions where you can find hot springs and pools of boiling mud. I also experience earthquakes. None of this is really surprising as I straddle the boundary between two seismic plates — the Pacific Plate and the Australian Plate.

Journey to the centre of the Earth…

'Descend into the crater of Yokul of Sneffels, which the shade of Scataris caresses before the Kalends of July, audacious traveller, and you will reach the centre of the Earth. I did it.'

So wrote Jules Verne in his science fiction novel *Journey to the centre of the Earth*, which was published in 1864. The novel describes a fascinating journey by the adventurous Professor Lidenbrock, his nephew Axel and their guide Hans to the centre of the Earth. Their quest begins with a descent into the crater of the extinct volcano Sneffels Yokul in Iceland. On their journey they discover oceans, forests and mountains illuminated by a strange 'electric' sky. They meet prehistoric beasts and other monsters, and survive terrifying storms. Eventually they get back to the surface by crawling out of the active volcano Mount Etna on the island of Sicily, hundreds of kilometres from the crater of Sneffels in Iceland.

Write your own science fiction short story about an attempted journey to the centre of the Earth. Before starting, think about what you would really expect to find beneath the surface and what sort of vehicle you would need to travel in.

Movers and shakers

1. How much do you remember about the structure of the Earth? On a piece of A4 paper, draw a diagram of the Earth and label the following parts of its structure:
   (a) crust
   (b) lithosphere
   (c) mantle
   (d) inner core
   (e) outer core.
2. The surface of the Earth is constantly undergoing change. Some of these changes may take thousands of years to have a noticeable effect on a landscape, while other events may cause rapid change in the Earth's surface. Consider the following agents of change:
   Earthquake
   Volcanic eruption
   Tsunami
   Landslide.
   Answer the questions below after discussing each event in a group.
   (a) Which of these do you think can happen in Australia?
   (b) Which event is the most dangerous to human life?
   (c) What causes these events to occur?

8.2 Continents on the move

8.2.1 Custard and continental drift

Early geologists believed that the Earth formed as a molten lump of rock that was slowly cooling from the outside in, causing the outer cooler layers to form a thin skin — kind of like the way that a skin forms on cooling custard. Just as the cooling custard skin contracts to form wrinkles, it was thought that the Earth's crust also formed wrinkles, and that these sections of raised crust formed the continents. During the late 1800s and early 1900s, scientists started to turn up evidence that indicated that the continents were moving. They interpreted this motion as being due to further cooling and contraction of the Earth, causing the 'wrinkles' in the surface to move relative to each other.

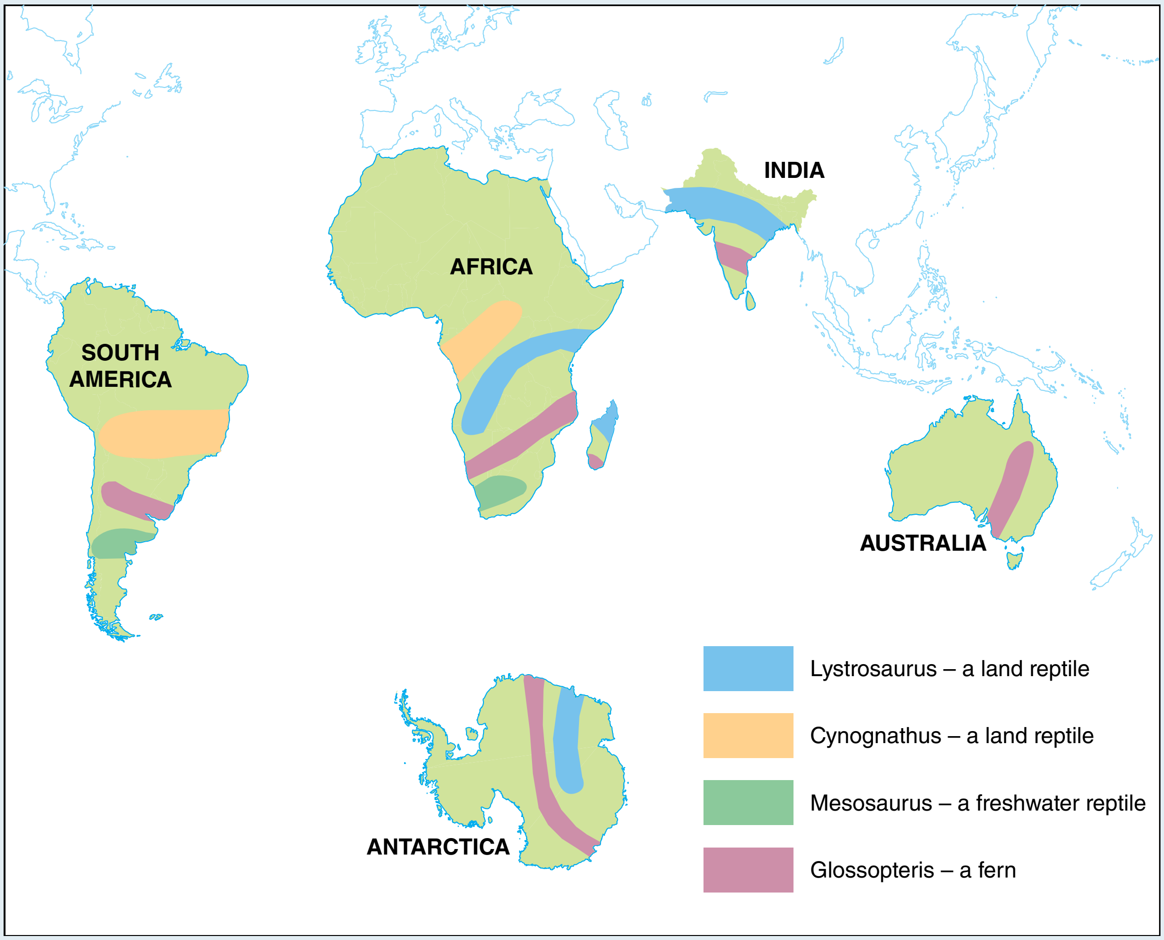
Wegener's theory of continental drift

However, not everyone was convinced by this model of the Earth's crust structure. In 1912, a German meteorologist named Alfred Wegener put forward an alternative idea to explain the movement of the continents. He had noticed that the continental coast on the eastern side of the southern Atlantic Ocean was almost identical in shape to the continental coast of the western side of the southern Atlantic Ocean, suggesting that the two continents had, at one time, been joined together. This idea was further supported by the fact that the distribution of fossils and rock types was the same on what would have been the connecting edges of the landmasses.

Wegener proposed that the continents on the Earth were not fixed but that they were 'floating' on denser material in the mantle below like leaves on water, and that these floating continents were constantly breaking apart from each other and rejoining in new combinations in a process he called **continental drift**. He believed that, at one time in the distant past, all of the Earth's continents had been part of a single 'supercontinent' that he called **Pangaea**.

INVESTIGATION 8.1

Continental drift



AIM: To follow Wegener's process and the observations that led him to propose the theory of continental drift

You will need:

enlarged copy of the map above

scissors

- Cut out the continents from the enlarged copy of the map above.
- Examine the distribution of fossils on each continent.
- Rearrange the continents into one supercontinent by matching the distribution of fossils.

Discussion

1. How do you think the distribution of fossils helps to prove Wegener's theory of continental drift?
2. Are there any other ways that the continents can be put together?

Continental shuffle

Using Wegener's ideas and the later theory of plate tectonics, scientists have been able to reconstruct the movement of the continents through geological history.

(a) 225 million years ago

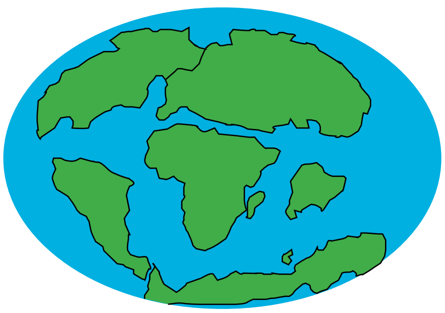
About 225 million years ago, all of the world's landmasses were joined together in the supercontinent Pangaea. Pangaea was surrounded by a vast sea called Panthalassa.

(b) 200 million years ago

Approximately 200 million years ago, the Tethys Sea formed as Pangaea began to split. The two continents that formed were called Laurasia and Gondwana. Laurasia included the landmasses that are now North America, Europe, Greenland and Asia. Gondwana included South America, Africa, Antarctica, India, Madagascar and Australia.

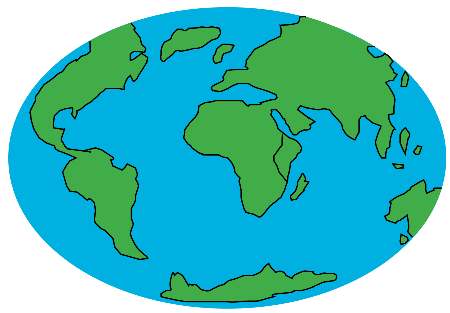
(c) 135 million years ago

Gondwana began to break up about 135 million years ago. The South Atlantic Ocean formed between Africa and South America.



(d) 65 million years ago

About 65 million years ago, Australia separated from Antarctica.



(e) The continents today

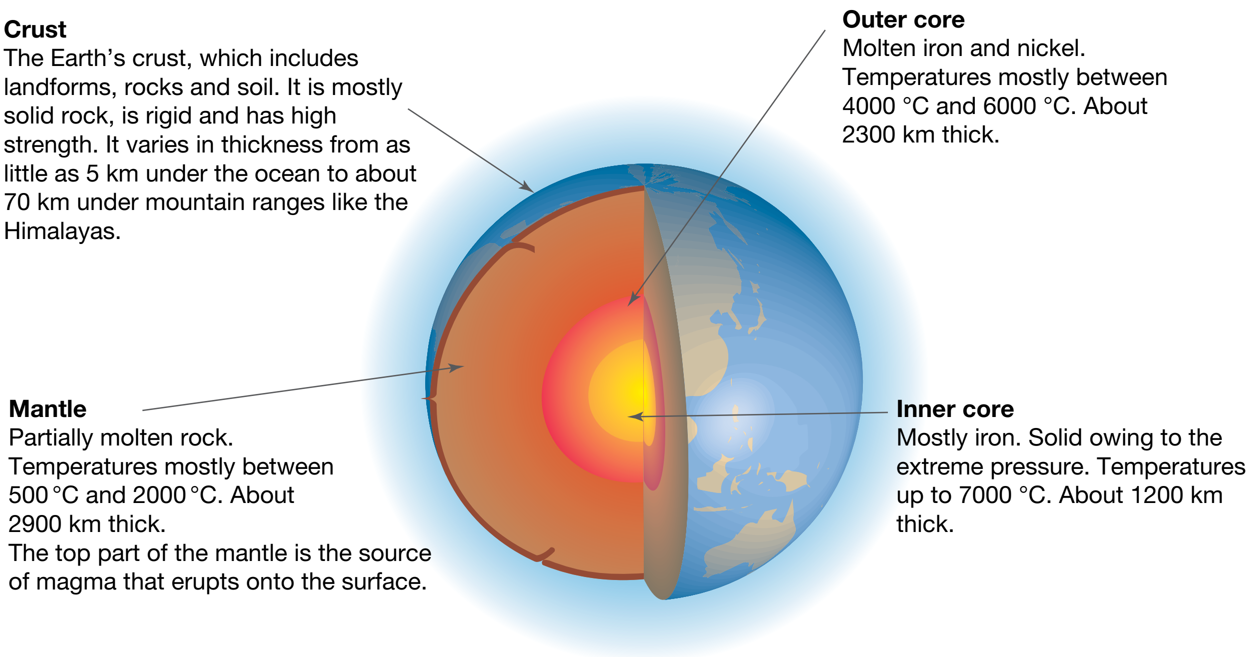
The fossilised *Glossopteris* leaf shown at right was found in New South Wales and dates back to 260 million years ago. Fossils of Glossopteris — an ancient seed fern — were instrumental in providing evidence for the Gondwanaland theory proposed in 1885 by the Austrian geologist Eduard Suess. According to Suess's theory, all of the southern hemisphere continents (Africa, India, Antarctica, Australia and South America) were once part of a larger southern landmass which he called Gondwanaland.

8.2.2 The Earth's structure

Scientists believe that the rocky inner planets including Earth would indeed have been nearly molten when they first formed due to the extreme heat generated by the collision of the fragments that created them. However, it wasn't just a big lump of rock that was pretty much the same material all the way through as the nineteenth century scientists believed.

As the Earth cooled and solidified, different materials began to separate out into layers. About five million years after the Earth was formed, the heavier elements such as iron and nickel sank towards the centre of the planet. The lighter rocky silicates (compounds of silicon and oxygen) floated on the surface, hardening as they cooled to form the Earth's crust. Eventually, four distinct layers were formed: the crust, the mantle, the outer core and the inner core.

The structure of the Earth



8.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** the assumptions early geologists made to explain the motion of continents.
2. **Explain** what Pangaea was.
3. **Recall** three pieces of evidence Wegener used to help support his theory of continental drift.
4. **Recall** what Panthalassa was.
5. **Identify** the sea that formed as Pangaea began to split.
6. In what way do modern theories of the early Earth agree with those of scientists in the nineteenth century?
   (a) **Recall** the names of the two continents formed from the split of Pangaea.
   (b) **Identify** the continent that Australia was a part of 140 million years ago.
7. Even though the inner core is hotter than the molten outer core, it is solid. **Explain** why this is the case.

Think

8. According to Wegener's theory of continental drift, upon which layer of the Earth are the continents floating?

Investigate

9. Use your library and the internet to **investigate** what the Eromanga Sea was, where it was located and what happened to it.
10. Alfred Wegener was not the first to notice the jigsaw puzzle way in which the South American and African continents' coastlines fit so neatly together. Nor was he the first to think that at one stage all of the continents might once have been joined up. For the most part, the theories that the scientists before Wegener came up with to explain how the continents were formed and separated, or even how the Earth was structured, were pretty wide of the mark. However, the work of Wegener owed a lot to the theories that came before it.
    (a) Select one of the following theories to study:
    - Expanding Earth Theory
    - Theory of Geological Uplift
    - Hollow Earth Theory
    - Contraction Theory

    (b) Use the library or internet to find out more about this theory. Here are some guidelines:
    (i) What was the main idea of the theory?
    (ii) How did this theory differ from our present ideas about the Earth?
    (iii) When was this theory popular?
    (iv) Who supported or proposed this theory?
    (v) What evidence was used to support the theory?
    (vi) What arguments were there against the theory?
    (vii) If this theory was correct, how will the Earth be different in the distant future (say, 2 billion years)?

Create

11. **Construct** a poster that displays the names and distributions of fossils that can be found in Antarctica. On your poster, include a picture of what you think the landscape and environment of Antarctica would have looked like 200 million years ago.
12. Create a poster of the Earth that shows the four main layers beneath the surface and the important characteristics of each layer.

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Complete this digital doc: Worksheet 8.1: Continental drift (doc-12782)

8.3 Plate tectonics

Science as a human endeavour

8.3.1 Plates on the move

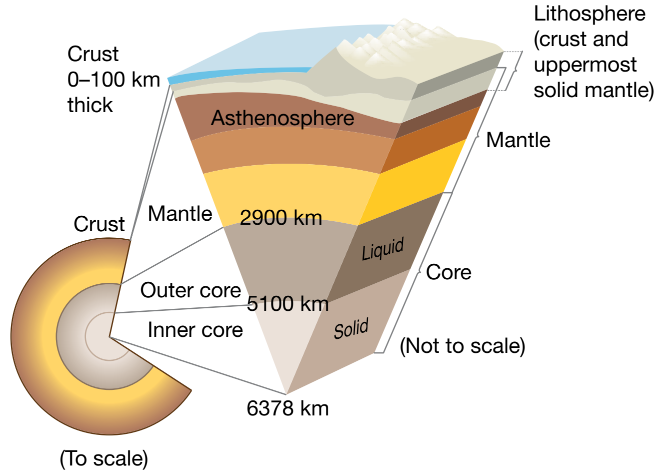
The theory of **plate tectonics** grew out of the initial conception of continental drift. Plate tectonic theory suggests that the Earth's lithosphere is not a uniform unbroken covering, but is divided into a number of 'plates'

The lithosphere

The crust and the upper mantle together make up a structure known as the **lithosphere** (from the Greek word *lithos* = rock). Rather than being a continuous shell like the coating on the outside of a Jaffa, the lithosphere is made up of 10 major and many minor separate plates much like a giant jigsaw puzzle. The lithosphere varies in thickness from an average of 100 km under the older ocean basins up to 300 km under the continental shields.

The plates of the lithosphere float on a layer of magma that can be up to 200 km thick. This is called the **asthenosphere**. The asthenosphere is actually more of a solid than a liquid even though it is very hot — over 1500 °C — simply because of the high pressure that the material is under. This high pressure squeezes the particles of the upper mantle much closer together than they would normally be at that temperature on the Earth's surface.

The lithosphere and the asthenosphere



Convection currents

Convection currents in the mantle keep the magma moving — the hot, less dense magma rises while cooler, heavier magma sinks. These currents move the plates that sit on top. In some places, the plates are forced together and at others they are drawn apart.

INVESTIGATION 8.2

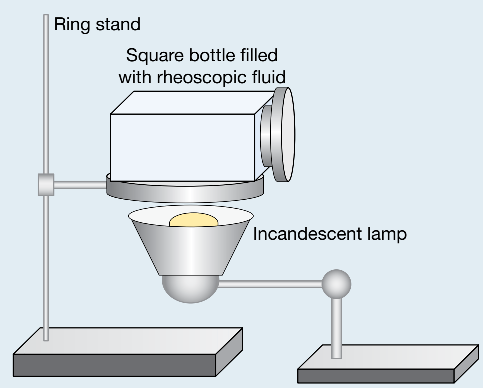
Convection currents (teacher demonstration)

AIM: To observe the process of heat transfer through convection and observe the motion of convection currents

You will need:

incandescent desk lamp with 75-W bulb
rheoscopic fluid (preferably coloured)
a glass bottle with square sides
ring stand

- Shake the bottle of rheoscopic fluid to ensure it is thoroughly mixed.
- Fill the bottle completely with rheoscopic fluid, being careful not to leave any pockets of air. Screw the cap on tightly.
- Place the bottle on the ring stand as shown in the diagram at right.
- Place the lamp directly under the centre of the bottle as shown.
- Turn on the lamp and, after about 10 minutes, you will be able to observe the convection currents that begin to form from the side of the bottle. Look at the currents from the top as well.



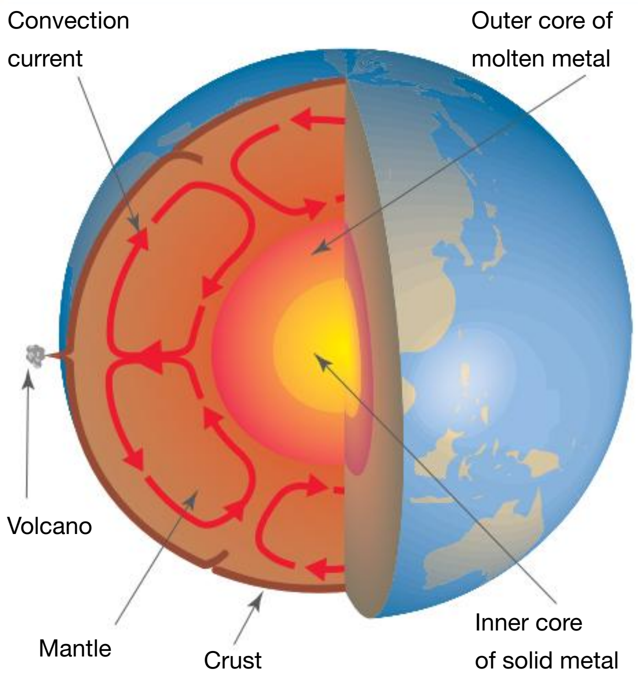
Discussion

1. Draw a simplified diagram showing the motion of the convection currents from the side and when viewed from the top. How do you explain the differences in the motion shown in the two diagrams?
2. Do you think that the convection in the mantle would be faster or slower than those produced in this investigation? Explain your reasoning.
3. A material called rheoscopic fluid was used in this investigation. What other materials do you think could be used instead? Try them out and see which would be the best replacements.

The map below shows the location of some of the major plates and boundaries. The location of some of the boundaries is still not certain. These are shown on the map by dotted lines. Some of the plates are very large, while others are quite small.

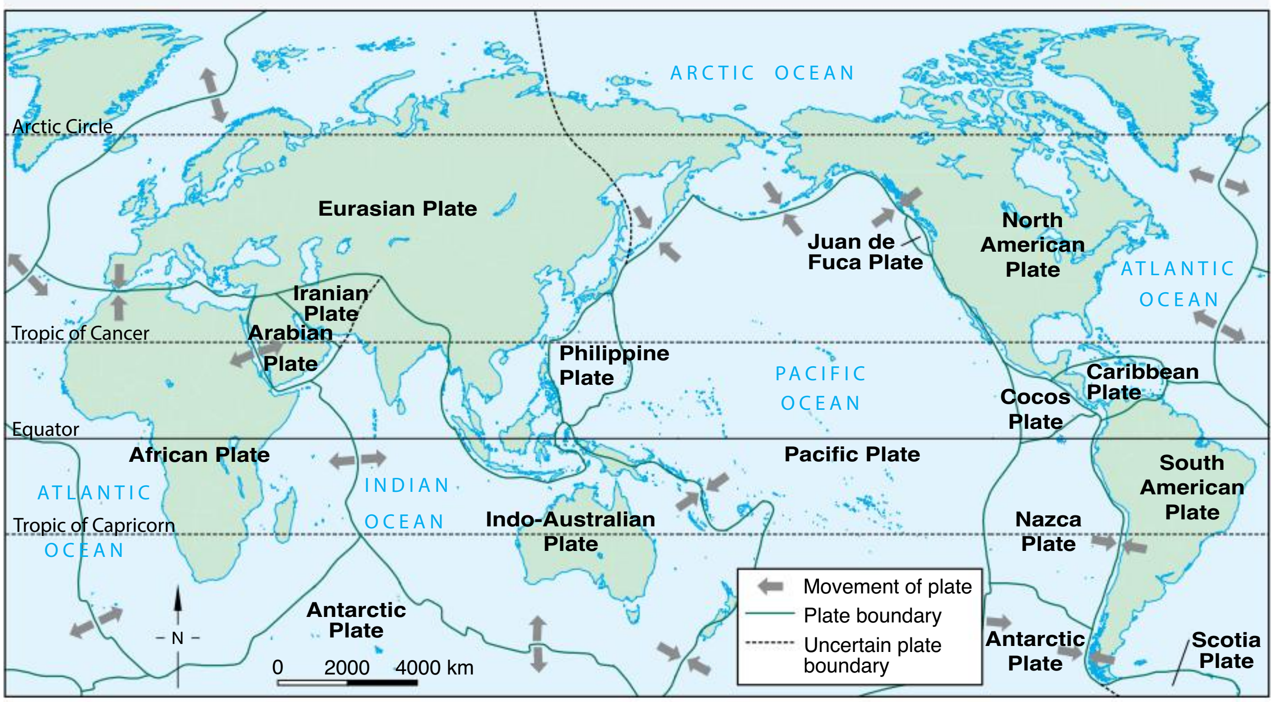
The plates can consist of two types of crustal material with an underlying layer of mantle material. The continents are made up of **continental crust**, which is between 30 km and 70 km thick. The plates beneath the oceans consist of oceanic crust. Since it does not have the build-up of land on it, oceanic crust is much thinner than continental crust and has an average thickness of just over 6 km. It is also a little denser than continental crust due to differences in its chemical composition. Due to the larger sizes of the oceanic plates, there is a greater proportion of oceanic crust than continental making up the lithosphere.

Convection currents within the mantle



About 30 plates make up the Earth's lithosphere and these move very slowly — usually only a few centimetres in a year. This is slower than the speed at which your fingernails grow!

A simplified map showing the major tectonic plates that make up the Earth's crust. The arrows show the direction of plate movement.



8.3.2 When plates meet

Where two plates meet at a boundary, the plates will be moving away from each other (divergence), sliding past each other (translation) or colliding with each other (convergence).

Spreading plates

Where plates diverge, magma from the mantle spews out onto the Earth's surface and forms a ridge of volcanoes. Two very long volcanic ridges of this type are found under the Atlantic and Pacific oceans. The Mid-Atlantic Ridge spans the length of the world, from Pole to Pole. The East Pacific Rise runs from Mexico to the South Pole.

We often don't feel the explosions from these underwater volcanoes because the oceans absorb the effect. However, scientists know that some tsunamis are the result of underwater volcanic activity.

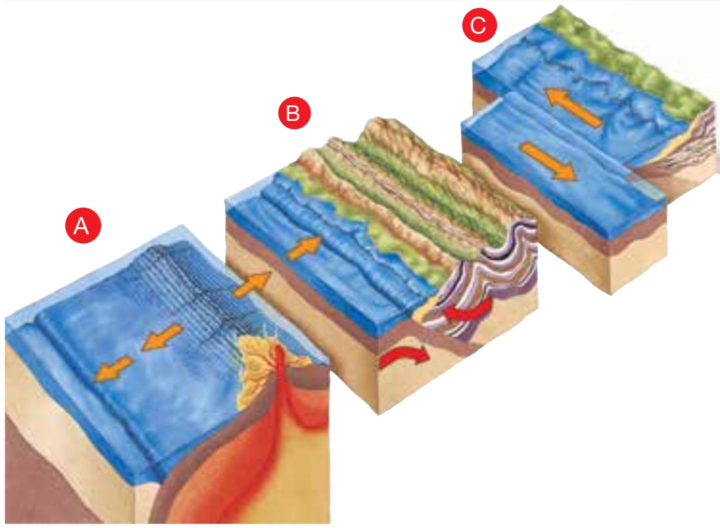
Sliding plates

California, in North America, experiences many earthquakes. The earthquakes there are caused by the edges of two plates sliding past each other. The plates do not slide smoothly; they get jammed together and the pressure builds up. Suddenly, the plates jolt past each other and start sliding again.

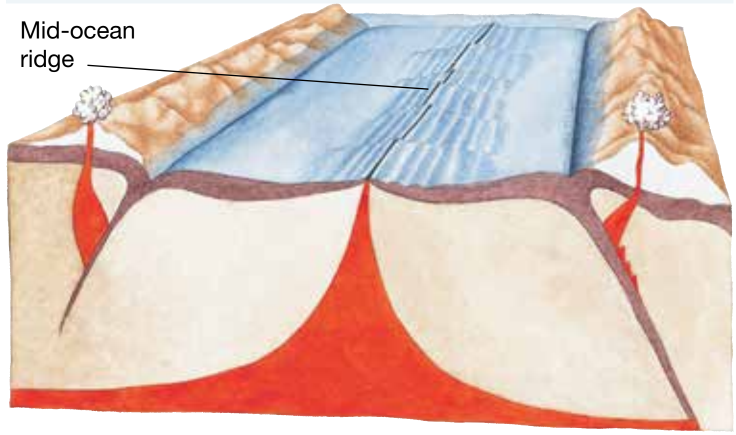
Colliding plates

The edges of some plates move towards each other. Plates that collide with each other are called **converging plates**. If one plate is made from oceanic crust and the other plate is continental crust, the edge of the oceanic plate sinks under the lighter continental plate. The areas where this happens are called **subduction zones**. Deep ocean trenches form along subduction zones. When plates sink under each other, huge amounts of heat and friction are produced. The heat and friction result in earthquakes and volcanic activity.

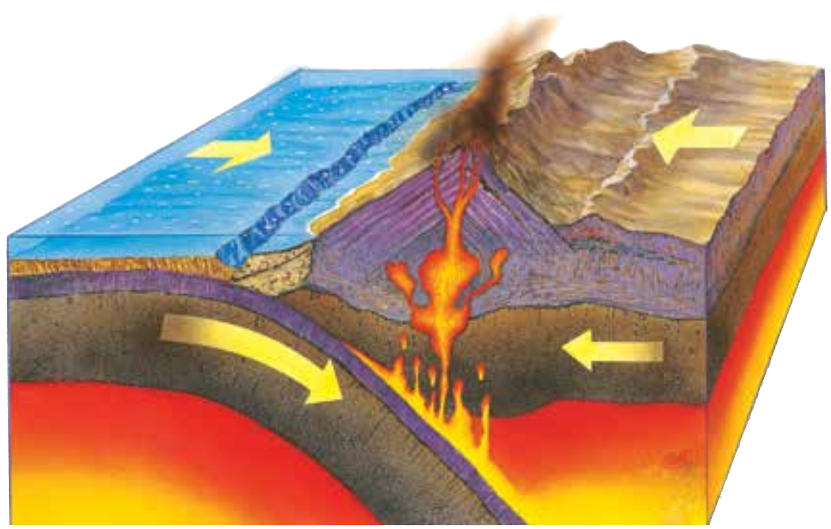
(a) Plate divergence (b) plate convergence (c) plate translation



A mid-ocean ridge forms when magma spews to the surface between plates that are diverging (moving apart).



Oceanic crust melts as it sinks under continental crust. Magma bursts through the crust to form a volcano. An example of this type of plate boundary is found along the western coastline of South America.

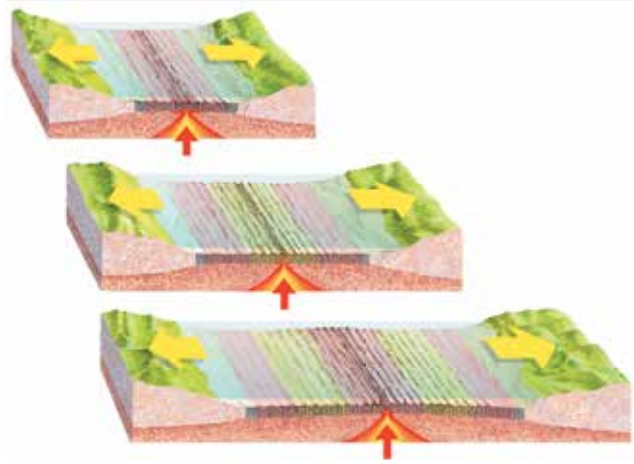


8.3.3 The evidence for plate tectonics

There is a variety of strong evidence for the theory of plate tectonics, including:

- 'chains' of volcanoes and regions of high seismic activity that appear to mark plate boundaries
- increasing height of mountain ranges such as the Himalayas
- the movement of the continents, which is able to be tracked over time using global positioning systems (GPS)
- rocks further away from the midlines of mid-ocean ridges are older than those that are closer to the midlines. The age of the rocks can be confirmed by using radioisotope dating techniques and paleomagnetism (see at right). This supports the idea that new rock is being formed in the middle of ocean ridges, continuously pushing the older rock aside.

Paleomagnetism in sea floor spreading. New sea floor (top) is formed at a mid-ocean ridge by upwelling lava (red arrow). Over millions of years the new rock fills the gap left as the continents drift apart (yellow arrows). As the volcanic rocks solidify, they retain the magnetism that was given to them by the Earth's magnetic field at the time. The Earth's magnetic field reverses periodically (approximately every 250 000–600 000 years), and this is shown by changes in the magnetism of these rocks (alternating red and green strips, bottom).

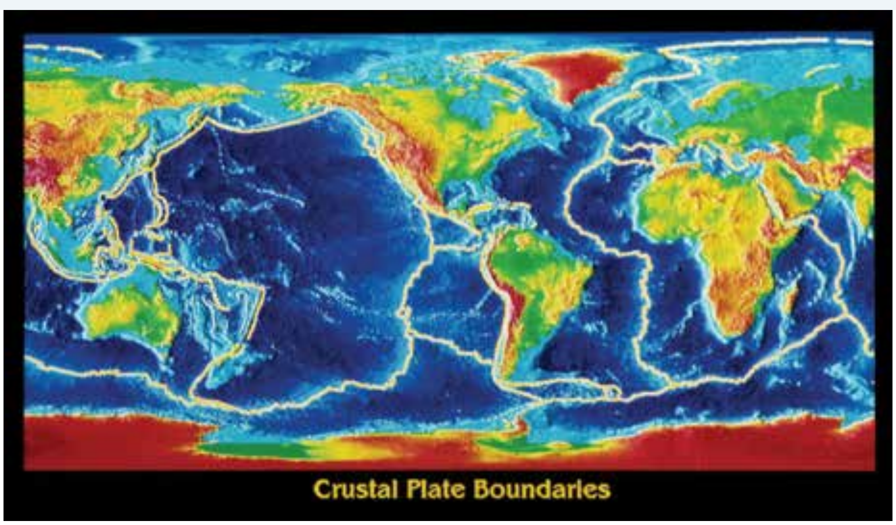


HOW ABOUT THAT!

Fossils of ancient sea creatures can be found at the top of the Himalayas, thousands of metres above sea level. How did they get there?

If you look at a map of the world, you will notice that India is joined to Asia. But that was not always the case. India has been moving towards Asia since it broke away from Gondwana millions of years ago. At first, seas separated the two lands. But now, the Indo–Australian Plate and the Eurasian Plate have collided. The current edges of these plates are both made of continental crust, so one plate will not easily slide under the other. Instead, the two are crumpling against each other, forming the Himalaya Mountains. Sediments that once lay at the bottom of the sea between the two landmasses have been forced upward and can be found at the peaks of the mountain range.

Map showing the topography of the Earth's land and sea floors, as well as crustal plate boundaries.



8.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** an example of where diverging plates are found on Earth.
2. **Identify** a place where two plates are sliding past each other.
3. **Identify** on which plate India is found.
4. **Recall** what type of plate boundary is associated with ocean trenches.
5. If the Earth's surface consists of moving plates, **explain** what the plates are moving on.
6. State one location on Earth where:
   (a) two plates are sliding past each other
   (b) subduction is occurring
   (c) volcanoes have formed away from the edges of plates.
7. **Compare** oceanic plates with continental plates.
8. What is the (a) lithosphere (b) asthenosphere?
9. **Describe** the evidence that exists for the spreading of mid-ocean ridges.
10. Use the **Plate tectonics** weblink in the Resources tab to answer the following questions about the changes that take place at plate boundaries.
    (a) **Describe** and compare convergent and divergent boundaries.
    (b) Are divergent boundaries constructive or destructive boundaries? **Explain** your answer.
    (c) What drives the formation of mid-ocean ridges?
    (d) **Explain** how scientists were able to prove that new crust was being formed at mid-ocean ridges.
    (e) At which type of plate boundary are the Earth's major earthquakes most likely to occur?

Think

11. **Explain** why earthquakes are felt in the regions surrounding the Himalayas.
12. The theory of continental drift was first proposed in 1912, over 50 years before the theory of plate tectonics was put forward. However, the evidence for the theory of continental drift also supports the theory of plate tectonics. **Explain** the difference between the two theories.
13. The plates that make up the Earth's crust move only a few centimetres each year. Do some calculations to **assess** if it is possible for Australia to have moved as far from South America as it is today.
14. **Explain** why the climate of most of the Australian continent has changed from cold to hot and dry during the past 65 million years.

Investigate

15. Find out what the Mohorevic Discontinuity is.
16. Research and report on the use of sonar in mapping the ocean floor.
17. Find out how climate change, whether due to the northward movement of the Indo–Australian Plate or global warming, is likely to affect amphibians such as frogs and toads.

Create

18. **Construct** a model of converging continental crust. Use two piles of paper to represent the two sections of crust. Push the two piles of paper together.
    (a) What happens at the point where the paper piles meet?
    (b) **Describe** how this relates to the way the Himalayas have formed.
    (c) What would you expect the rocks to look like in a mountain range formed by converging plates?
19. Test your knowledge of plate boundaries by completing the **Does the Earth move?**

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Try out this interactivity: Does the Earth move? (int-0674)

Complete this digital doc: Worksheet 8.2: Plate tectonics (doc-12783)

8.4 Rocks under pressure

8.4.1 Bending without breaking

Folded limestone on the Greek island of Crete

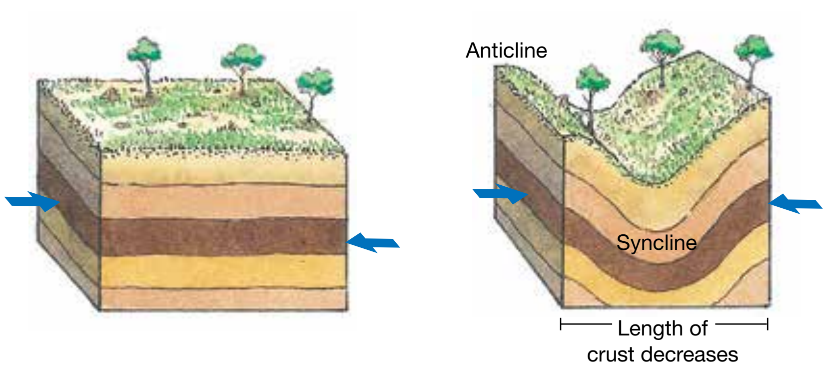
It's hard to imagine the size of the forces that are responsible for the movement of the Earth's plates. These forces are so large they can effortlessly snap rocks or fold them into intricate patterns. Broken and folded rocks can be found near the edges of colliding plates, but they are also found in areas far from plate boundaries.

When you hold a sheet of paper with one hand on each end and then move the ends towards each other, the paper bends upwards or downwards.

The forces beneath the Earth are so large that layers of rock bend and crumple without breaking, just as the paper does. This process is known as **folding**. Most of the major mountain ranges around the Earth have been shaped in this way. The Himalayas have been formed by the folding of rock as two of the plates that make up the Earth's crust slowly collide. They are still rising as the plates continue to grind into each other.

Folds that bend upwards are called **anticlines**. Those that bend downwards are called **synclines**. Generally anticlines and synclines are formed well below the surface of the Earth and are not visible unless they are exposed by erosion of softer rock. They can often be seen in road cuttings or in cliffs formed by fast-flowing streams.

Forces on solid layers of rock fold them into anticlines and synclines.



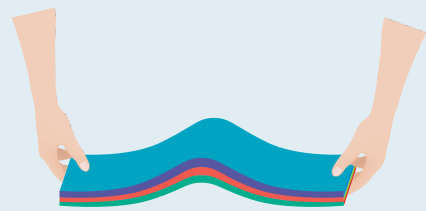
INVESTIGATION 8.3

Modelling folds

AIM: To model the way in which forces cause rocks to fold

Rocks are usually folded well below the Earth's surface. The anticlines and synclines can be seen only along road cuttings or where erosion has exposed the layers of rock. A model is a useful way to describe how folded rocks would appear under the surface.

You will need:
3 or 4 pieces of differently coloured plasticine
knife or blade
board



- Roll the pieces of plasticine into 1 cm thick layers.
- Place the layers of coloured plasticine on top of each other. Press down lightly on the layers, so that they stick together.
- With the palms of your hands, very gently compress the layers from the side.
- Model the processes of weathering and erosion on your plasticine layers.

Discussion

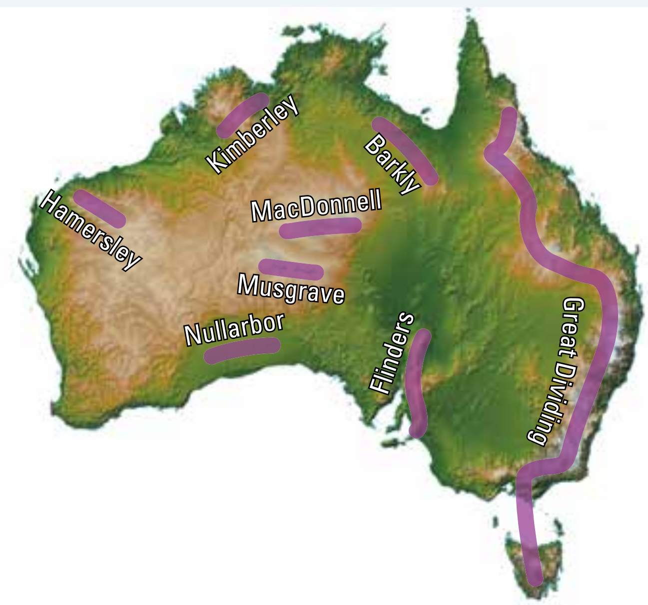
1. Describe the appearance of the plasticine when the layers are compressed.
2. Draw a diagram of the plasticine after compression, labelling anticlines and synclines.
3. Imagine that the rock layers are eroded at the Earth's surface. Draw diagrams of the eroded layers when viewed from above and when viewed from the side. Label the oldest and youngest layers. (Remember that the oldest layers are deposited before the younger ones.)

Fold mountains

The process of mountain building is called **orogeny**.

Australia's Great Dividing Range, which stretches all the way from northern Queensland to Tasmania, was formed by folding. It is actually a chain of separate mountain ranges, including the Carnarvon Range in central Queensland, the Blue Mountains of New South Wales, the Australian Alps, the Dandenong Ranges near Melbourne and the Central highlands of Tasmania.

Australia's Great Dividing Range was formed by folding as a result of the movement of the Earth's tectonic plates.



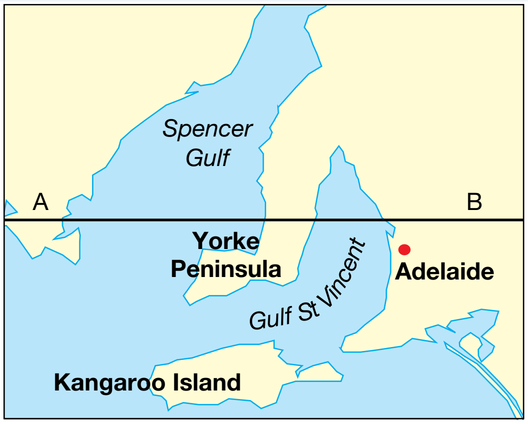
8.4.2 Whose fault is that?

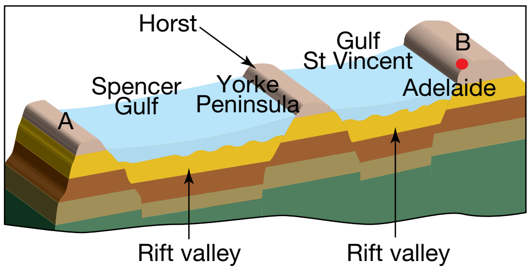
Sometimes rocks crack as a result of the huge forces acting on them. Once movement occurs along a crack, it is called a **fault**.

The Gulf region of South Australia has been formed by a series of faults. Two blocks of crust have dropped down between faults to form Spencer Gulf and Gulf St Vincent. Between these sunken blocks, which are called **rift valleys**, is a block that has been pushed upwards by the forces below. This block, called a **horst**, has formed Yorke Peninsula. The movement along these faults is responsible for the occasional earthquakes in the Adelaide area.

If movement along a fault is sideways, that is, where the blocks of crust slip horizontally past each other, it is called a **transform fault**. The San Andreas Fault in California is a transform fault. It stretches about 1200 km along the coast, passing through San Francisco and to the north of Los Angeles. A large movement of the blocks on either side of this fault line in 1989 created a major earthquake in San Francisco, killing at least 62 people. The earthquakes experienced in this area in recent years appear to be caused by a build-up of pressure along the fault. Scientists believe that it will not be long before the pressure is relieved through a catastrophic earthquake.

The Gulf region of South Australia has been formed by a series of faults.



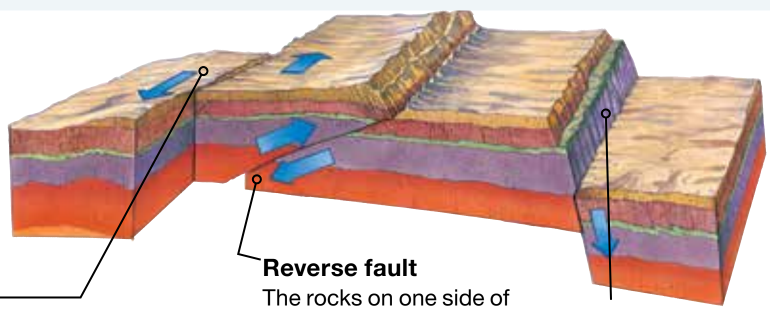


The San Andreas Fault

HOW ABOUT THAT!

Mount Everest in the Himalayas is considered to be the highest mountain in the world, with a summit rising to 8848 m above sea level. It is not, however, the tallest mountain. The tallest mountain is Mauna Kea in Hawaii, which has a height of 10 203 m, but only 4245 m of this is above sea level. On a universal scale, neither of them can compare to Olympus Mons on Mars, which stands 26 000 m above its surroundings!

Three types of fault



Transform fault

Transform faults are those where rocks move sideways along a fracture. A large-scale, transform fault is the San Andreas Fault, near California. This fault is the result of two of the Earth's plates sliding past each other. You can recognise smaller transform faults by looking at surface rocks from above. The rocks on either side of the crack will be mismatched.

Reverse fault

The rocks on one side of a *reverse fault* have been forced upwards. Reverse faults appear in rocks that have been squeezed together. Large-scale reverse faults create mountains with one steep side. Subducting plates can cause this type of fault. An example is the Japan Alps.

Normal fault

The rocks on one side of a *normal fault* slip downwards. Normal faults appear in rocks that have been stretched. Large-scale normal faults create long cliff faces. Look for small-scale normal faults along road cuttings. They appear as a crack in the rock, with mismatched layers on either side of the crack.

INVESTIGATION 8.4

Modelling faults

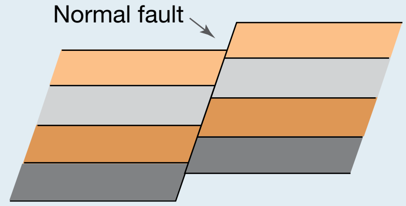
AIM: To model the formation of faults in rock layer

You will need:

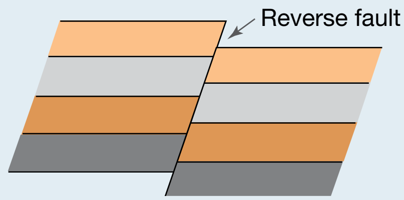
3 or 4 pieces of different coloured plasticine
thin sheet of polystyrene
knife or blade

- Place the first piece of plasticine on the bench and flatten it into a rectangular shape. Do not make it too thin. Cut a piece of polystyrene the same size, and fit it over the plasticine rectangle.
- Add two or three more layers of plasticine with a layer of polystyrene between each layer.
- Cut through the layers on an angle as shown in the diagram at right. Use the two parts to model each of the two types of fault shown at right.

Normal fault



Reverse fault



Discussion

1. Draw a diagram of each fault. Label it with arrows to show the direction in which each block moved to create the fault.
2. Describe the plate movement that could be responsible for each type of fault.

8.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Describe** what folding is and how it is caused.
2. **Explain** why the Himalayas are still growing in height.
3. **Recall** the difference between a syncline and an anticline.
4. **Explain** what causes earthquakes along the San Andreas Fault.
5. How can you differentiate between a reverse fault and a normal fault?
6. **Describe** three types of fault that occur in rocks.
7. **Identify** the type of fault that is created when a rock is pulled apart.
8. **Identify** an example of a landform that has been created by a fault.

Think

9. **Explain** with the aid of some labelled diagrams how mountains could be formed by faulting.
10. There is a lot of faulting as well as folding in the Himalayas. **Explain** how it is possible for folding mountains to develop faults later in their geological history.

Create

11. **Construct** a model to demonstrate the formation of the Gulf region of South Australia.

Imagine

12. Imagine that you were offered the chance to spend a year in a high school in a leafy northern suburb of Los Angeles, just two kilometres from the San Andreas Fault. Would you accept the offer? Explain your response.

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Complete this digital doc: Worksheet 8.3: Folding and faulting (doc-12784)

8.5 Shake, rattle and roll!

8.5.1 What triggers an earthquake?

Not surprisingly, the enormous forces exerted on and by the tectonic plates have an effect on the Earth's surface. While the movement of these plates is generally very slow, the way in which they interact can cause enormous pressures to build up in the mantle and at the interface of the plates themselves. When these pressures are released, the results can be sudden, catastrophic and — literally — earthshaking!

The convection currents in the mantle cause the tectonic plates to move past each other, away from each other or underneath one another. However, this motion is by no means smooth, and sometimes the plates lock together and jam in position. As the convection currents are still trying to make the plates move, enormous strain builds up in these jammed plates. As the strain increases, the rocks of the plate get distorted. When the strain forces finally get big enough to overcome the jamming of the plates, the plates suddenly snap into a new position. This rapid movement causes rocks in the plate to break and energy to be released. About 5 per cent of this energy travels through the Earth in the form of waves. These are called **seismic waves** and it is the vibration of the Earth in response to the passage of these waves that we call an **earthquake**.

The constant movement of the Earth's plates is responsible for over 100 000 earthquakes around the world each year. Luckily, most of these are so weak that they are not felt.

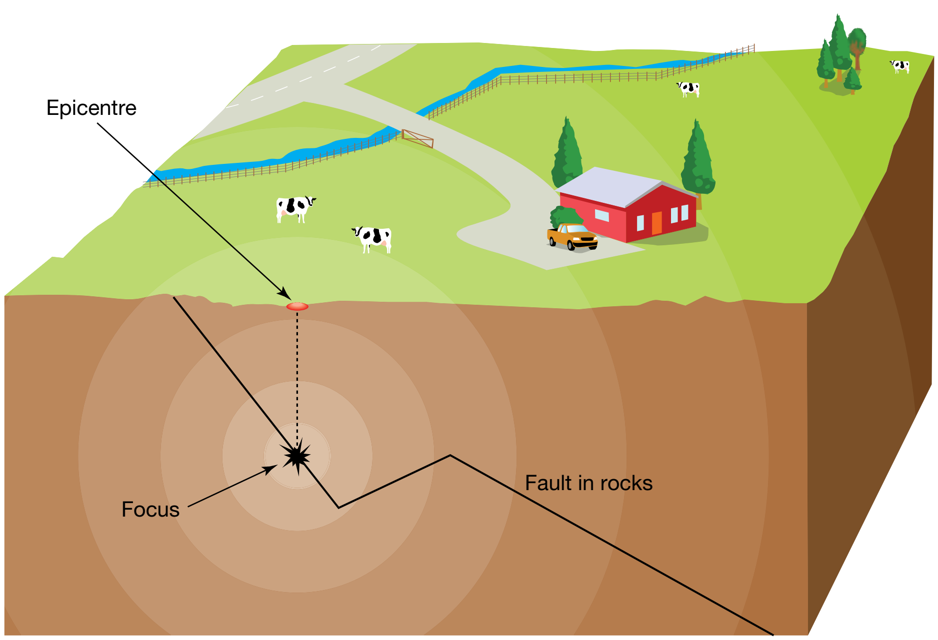
The world's major earthquakes occur near plate boundaries. Smaller earthquakes can occur wherever there is movement in the ground, such as along a fault line.

8.5.2 The anatomy of an earthquake

The location in the Earth's crust where the rocks fracture generating the earthquake is called the focus. The seismic waves radiate away from the focus. Most of the time, the focus is located within 8 km of the Earth's surface. Earthquakes can be classified according to the depth of the focus:

- shallow focus: less than 35 km from the surface
- intermediate focus: between 35 and 300 km from the surface
- **deep focus:** between 300 and 700 km from the surface.

The **epicentre** of an earthquake is the point on the surface directly above the focus.



The destructive power of an earthquake in any location also depends on its distance from the epicentre. For example, the Tennant Creek earthquake of 1988 in the Northern Territory had a Richter magnitude of 6.7; however, only two buildings and the natural gas pipeline were damaged. The epicentre of the earthquake was 40 km north of the town. Yet the earthquake that devastated Newcastle in New South Wales in 1989 registered 5.6 on the Richter scale, killed 13 people, hospitalised 160 others, demolished 300 buildings and damaged tens of thousands more. The epicentre of that earthquake was only 5 km west of the city.

Seismic waves

Energy released during an earthquake travels in the form of waves. There are three main types of wave that are generated by earthquakes: P-waves, S-waves and L-waves. These waves differ in their speed and the regions of the Earth through which they travel.

P-waves (or **primary waves**) are compression waves, moving through the Earth in the same way that sound waves move through air. They are the fastest of the seismic waves and so are the first waves to arrive at a seismometer.

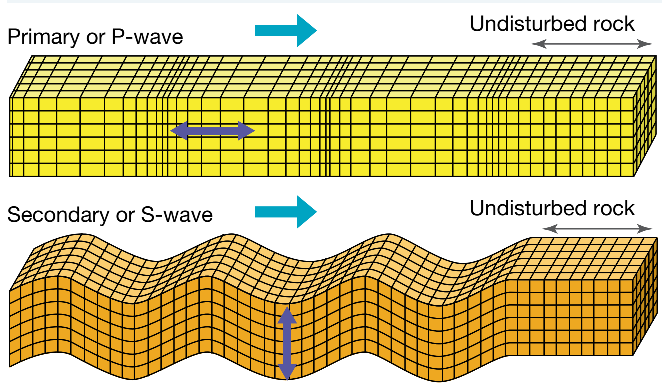
After the P-waves, the second sets of waves to be detected are the **secondary** waves or **S-waves**. These travel in the form of transverse waves. The ripples on the surface of a pool when a rock has been dropped into it form transverse waves.

As the P-waves and the S-waves are both able to travel through the interior of the Earth, they are said to be **body waves**.

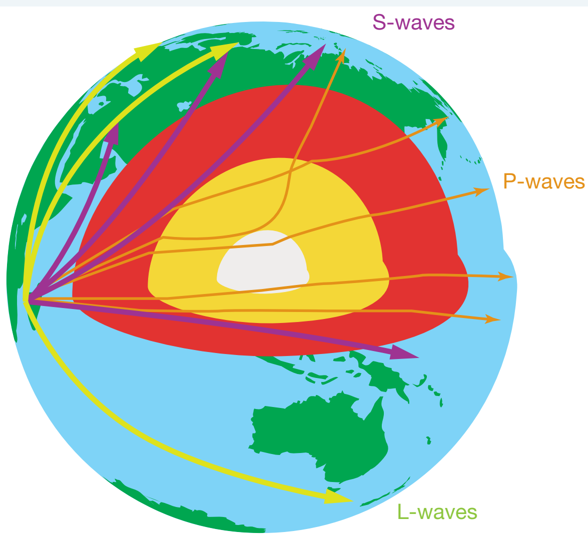
L-waves are **surface waves** and travel around the Earth. While they travel much more slowly than either the P-waves or S-waves, it is these surface waves that are responsible for the majority of an earthquake's destructive power. This is because all of the L-wave energy is distributed across the surface of the Earth rather than being spread out through the Earth's interior as in the case of P- and S-waves.

Some of the destruction caused by the December 1989 Newcastle earthquake

P-waves travel through the earth as compression waves while S-waves are transverse waves.



P-waves are able to travel through the inner and outer core as well as the mantle; S-waves travel in the mantle; L-waves travel on the Earth's surface.



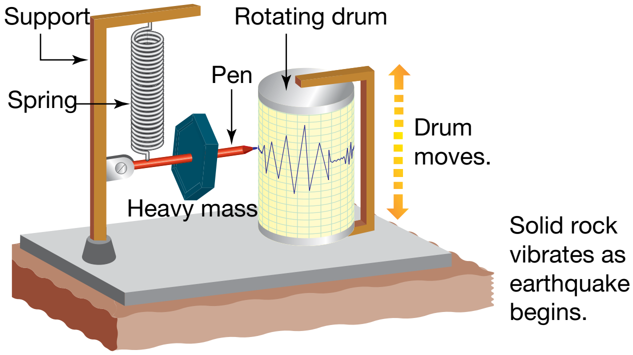
8.5.3 Measuring earthquakes

The waves travelling from the focus can be detected using a device called a **seismometer**. The record of seismic activity obtained from a seismometer is called a **seismogram** on which the P-, S- and L-waves appear as a continuous sequence of wriggles. The height of these wriggles indicates the intensity of the waves that are being recorded, with larger amplitudes coinciding with more energetic waves.

The seismometer itself may be located thousands of kilometres away from the device which produces the seismogram. The frame of the seismometer is attached to a heavy base (often concrete and steel) which is anchored securely to solid rock. When the rock vibrates, the frame vibrates with it. A heavy mass — which can be up to 450 kg in large mechanical seismometers — is attached to the frame with a spring. When the frame moves, inertia causes the mass to remain steady. The movement of the frame relative to the mass is detected electronically and recorded.

In older versions, known as **seismographs**, the movement of the weight causes the movement of a pen against a continuously rolling paper strip.

An earthquake recorded on a seismograph. A strip of paper moves past a stationary pen. When the seismograph is jolted by the earthquake it jumps up and down. However, the pen is attached to the heavy mass which does not move. As the paper turns on the drum, the pen leaves a record of the vibrations.



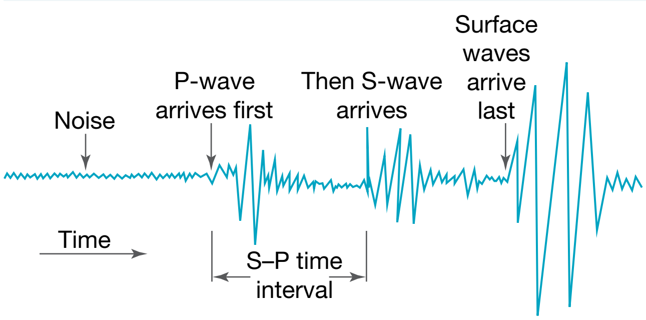
8.5.4 Interpreting a seismogram

Have you ever wondered how seismologists can tell where the epicentre of an earthquake is located, even if it is on the other side of the world or in the middle of an unpopulated region?

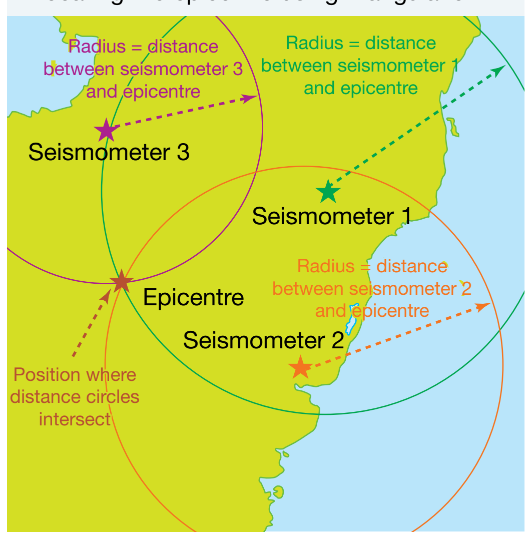
The location of an earthquake's epicentre is found by comparing the time interval that elapses between the arrival of the P-waves and the S-waves (called the S–P time interval) at different seismometer locations. For each location, seismologists use this time interval to calculate the distance between the epicentre and the seismometer.

By using readings from at least 3 different seismic stations, the position of the epicentre can be determined. This process is known as **triangulation**.

The time interval between the arrival of the P-waves and the S-waves at the seismometer allows seismologists to calculate the distance between the seismometer and the epicentre of an earthquake.



Locating the epicentre using triangulation



INVESTIGATION 8.5

Making a seismograph

AIM: To construct and use a model seismograph

You will need:

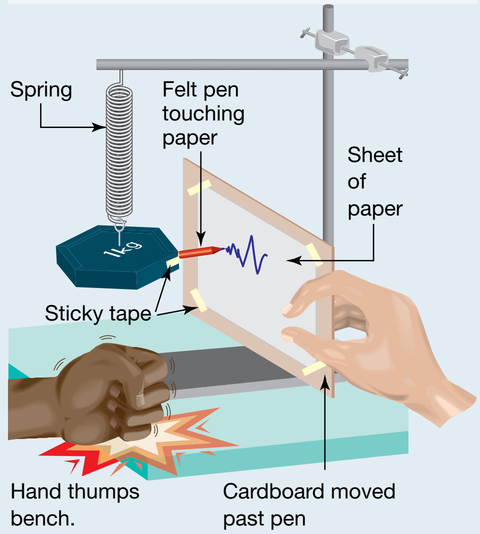
a retort stand, bosshead and rod
spring
cardboard
A4 paper
sticky tape
felt pen
500 g or 1 kg weight (or a can full of sand)

- Set up the equipment as shown in the diagram at right.
- Have your partner move the cardboard past the pen while you thump the surface on which your seismograph sits.

Discussion

1. Does the model work?
2. How could you improve the model?

A model seismograph



The Richter scale

The strength of an earthquake can be measured in a number of ways. The most well-known way of measuring the strength of earthquakes is the **Richter scale**.

The Richter scale measures the amount of energy released during an earthquake. The higher the Richter scale measurement, the more intense the earthquake. Each increase on the scale represents a 30 times increase in the energy released during the quake. So, an earthquake of magnitude 5 releases 30 times more energy than one that measures 4 on the scale.

Earthquakes that measure less than 2 on the scale occur more than 500 000 times each year around the world. These earthquakes are so weak that only very sensitive instruments can detect them. Earthquakes above magnitude 6 occur between 20 and 200 times each year. An earthquake of this size is felt strongly, and weak buildings will fall. Very intense earthquakes, measuring more than 8 on the Richter scale, do not occur often

The Richter scale

Richter magnitude	Description of effects
0	Smallest magnitude detectable by seismometer
1.0	Undetectable by humans Equivalent to the energy released by the detonation of 30 kg of TNT
2.0	Smallest magnitude that can be noticed by humans (Tremors of magnitudes less than this are called **microquakes**.)
<3.5	Generally noticeable by humans
3.5–5.4	Often felt but rarely cause damage Vibrations similar to those felt when a heavy truck drives past Objects on shelves may rattle or fall down
<6.0	Slight damage to well-designed buildings but can cause large cracks and material failure to poorly constructed buildings
6.1–6.9	Can be destructive over a 100 km wide area
7.0–7.9	Major earthquake Can cause serious damage over very large areas
≥8	Great earthquake Can cause serious damage in areas several hundreds of kilometres across

(up to 10 per year around the world). These earthquakes cause the total destruction of buildings, roads and bridges.

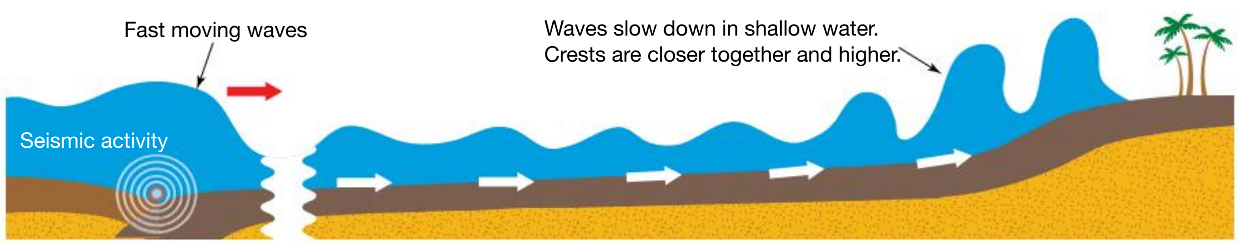
The Richter scale does not always give a true indication of the destructive power of an earthquake. In a crowded city, small earthquakes can cause many deaths, injuries and much damage, cutting off water, gas and electricity supplies, while larger earthquakes in remote areas cause little injury and damage.

The earthquake that devastated the city of Newcastle in New South Wales in December 1989 lasted only 12 seconds and registered only 5.5 on the Richter scale.

8.5.5 Waves of destruction

Earthquakes occurring under the ocean or near a coastline can cause the formation of giant ocean waves called **tsunamis**. A tsunami is not a single wave; in fact it is made up of a series of waves that travel across the ocean at speeds of up to 800 km/h — this is nearly as fast as an airplane!

A wave series forms when the water, which is displaced by an underwater earthquake or landslide, travels outwards from the disturbance just like ripples that form when a stone is dropped into a pond. In deep water, the waves are only a metre or so in height and separated by as much as 100 km. As the waves enter the shallow water along a coastline, they slow down. The waves further back start to catch up to the ones in front, causing the waves to increase in height as they bunch up. These waves can reach heights of 30 metres before they break onto the land. The massive body of water then moves inland, causing severe flooding and considerable loss of life and property.



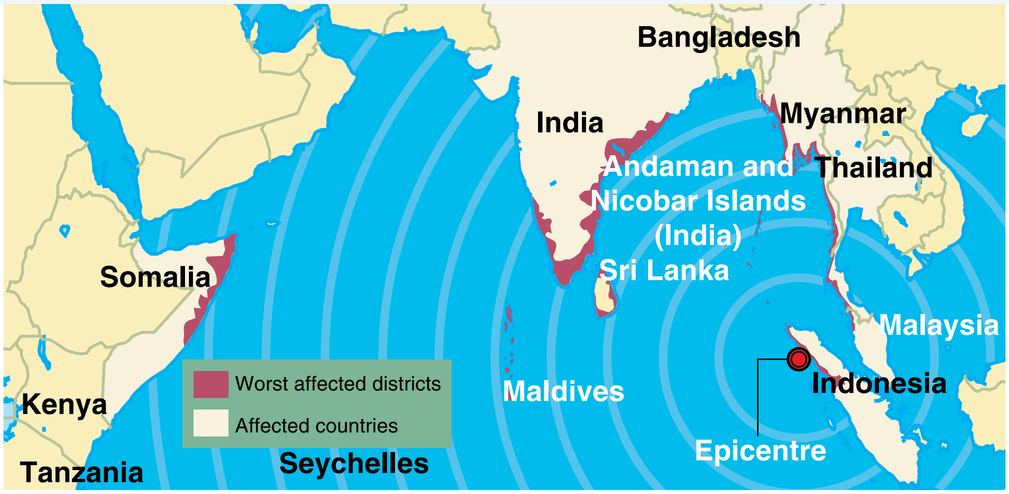
The 2004 Sumatra–Andaman tsunami was caused by an earthquake that had a magnitude of at least 9.0 and an epicentre just north of Simeulue Island in Indonesia. While most earthquakes only last a few seconds, the Sumatra–Andaman earthquake lasted several minutes and triggered secondary earthquakes as far away as Alaska. Around 200 000 people were killed, with over 14 000 people still missing. Worst hit was the Sumatran city of Banda Aceh (shown at right), where the tsunami pushed a 3 m high wall of water, mud and debris 10 km inland.

The Sumatran city of Banda Aceh after it was hit by the Sumatra–Andaman tsunami in 2004

The tsunami also caused widespread death and destruction in Sri Lanka, India and Thailand as well as Malaysia, Myanmar, Bangladesh and the Maldives.

The deadly wave even travelled as far as the east coast of Africa, more than 5000 km from the epicentre of the earthquake.

This map shows the huge area affected by the tsunami on 26 December 2004.



The world was again reminded of the destructive power of tsunamis in March 2011, when an earthquake struck that was of the same magnitude as the 2004 Sumatra–Andaman earthquake. The epicentre of this earthquake was only 70 km off the coast of the Japanese island of Honshu. The nearest major city was Sendai, where the port and airport were almost totally destroyed. In that city at least 670 people were killed and about 2200 were injured. Around 6900 houses were totally destroyed, with many more partially destroyed. Waves of up to 40 m high were recorded on the coast and some caused damage as far as 10 km inland.

Several nuclear reactors were shut down immediately following the earthquake that caused the tsunami. However, that wasn't enough to prevent meltdowns in three reactors at the Fukushima Daiichi Power Plant, resulting in explosions and the leakage of radiation into the atmosphere, water and soil.

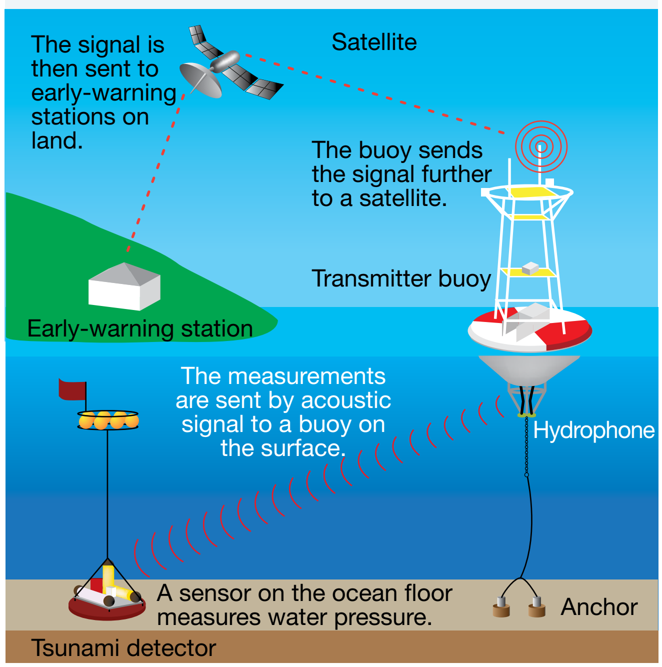
8.5.6 Predicting seismic events

Seismic events such as earthquakes and tsunamis kill thousands of people and cause enormous damage. It is difficult to predict exactly when these events will occur, but scientists use a number of different methods to try to get enough warning ahead of time for people to be evacuated from endangered regions.

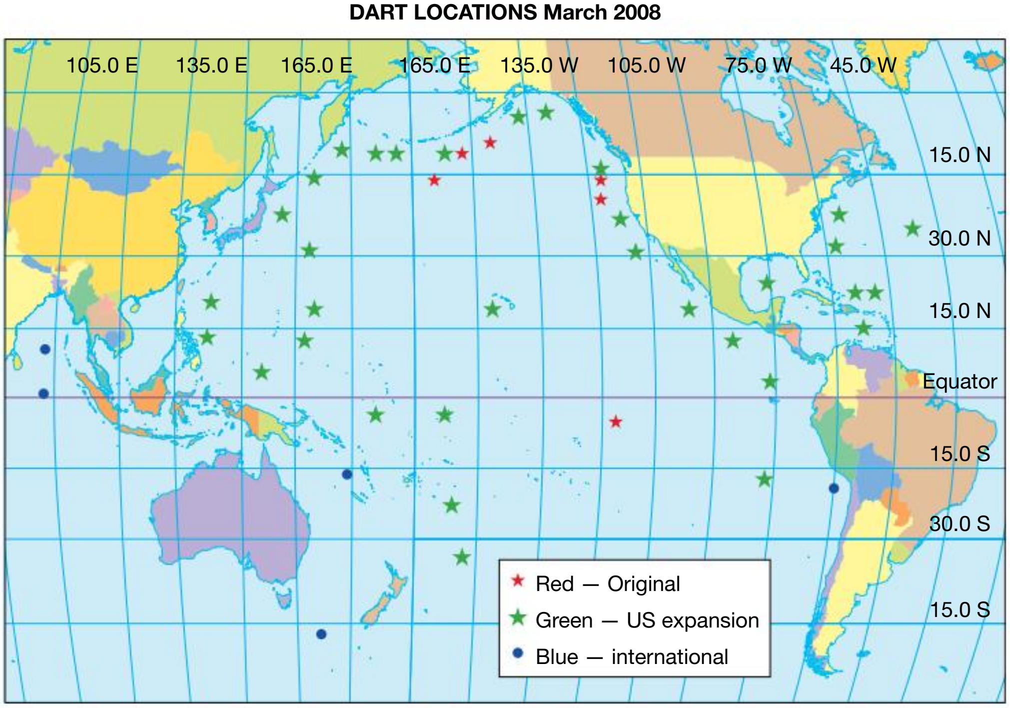
Earthquakes occur when jammed plates suddenly slip past each other, so seismologists (scientists who study earthquakes) monitor the movement of the tectonic plates along critical boundaries and fault lines. Sensors take readings to measure pressure build-ups that may indicate that the plates are about to slip.

The DART (Deep-ocean Assessment and Reporting of Tsunamis) system is made up of a series of buoys around the Pacific Ocean and parts of the Atlantic Ocean. When a buoy detects a sudden rise in sea level, which could indicate a tsunami, it sends information about sea motion in the area it is in to a tsunami warning centre. After confirming that a tsunami has formed, the centre issues evacuation alarms to the endangered coastlines.

How DART works



DART warning buoy locations



8.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. List some of the effects of earthquakes.
2. **Explain** how earthquakes occur.
3. **Distinguish** between an earthquake and a tremor.
4. What is the difference between the focus and the epicentre of an earthquake?
5. **Explain** why a tsunami only a few metres high in the open ocean can reach heights of up to 30 m by the time it reaches land.
6. **Explain** how seismologists are able to make predictions about the likelihood of an earthquake.
7. **Describe** the differences between P-waves, S-waves and L-waves.
8. State in which order the different seismic waves arrive at a seismometer.
9. **Identify** the area in which most tsunamis begin.
10. **Recall** what is measured by the Richter scale.
11. Why are P-waves and S-waves referred to as body waves?

Think

12. **Explain** why Indonesia experiences bigger earthquakes than Australia.
13. **Explain** why the DART system was unable to provide warning of the Sumatra–Andaman tsunami.
14. **Account for** the fact that areas as far away from Sumatra as Africa and Alaska could feel the effects of the Sumatra–Andaman tsunami.
15. **Explain** why Australia experiences earthquakes even though it is not near a plate boundary.
16. **Calculate** how much energy an earthquake that measures 6 on the Richter scale has in comparison to an earthquake that has a Richter magnitude of:
    (a) 4
    (b) 7
    (c) 2.
17. **Outline** some of the long-term consequences of the damage done to nuclear power stations by the Sendai tsunami.

Investigate

18. Some people refer to tsunamis as tidal waves. This is incorrect. Use the library or internet to **investigate** the difference between tidal waves and tsunamis.
19. **Investigate** why earthquakes are more likely to occur in some areas than in others.
20. Seismologists use the Mercalli Intensity scale to measure the extent of destruction that an earthquake causes. Research how this scale works and compare it with the Richter scale.
21. Use the internet or other resources to research and **compare** the 2004 Sumatra earthquake and the 2011 Japan earthquake. Write a report about the differences between the earthquakes and their consequences.

Using data

The table below shows the number of people killed in some of the major earthquakes in recent years.

Year	Location	Number of deaths (approx.)	Richter scale magnitude
1994	Los Angeles, USA	57	6.6
1995	Kobe, Japan	6 400	7.2
1999	Iznit, Turkey	17 000	7.4
2001	Gujarat, India	20 000	7.9
2003	Bam, Iran	26 000	6.6
2004	Sumatra, Indonesia	230 000	9.0
2008	East Sichuan, China	90 000	7.9
2010	Haiti (Caribbean Sea)	316 000	7.0
2011	Sendai, Japan	18 000	9.0

22. **Identify** which two earthquakes listed in the table above best show that the Richter scale measurement does not indicate the loss of life in earthquakes.
23. **Recall** what factors, apart from the Richter scale measurement, affect the likelihood of deaths occurring in an earthquake.
24. **Construct** a bar graph to display the Richter scale measurement of the earthquakes listed in the above table.
25. How much more energy was released by the 2004 Sumatra earthquake than the 2010 Haiti earthquake?
26. Suggest why there were more fatalities as a result of the Haiti earthquake.

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Explore more with this weblink: Tsunami

Complete this digital doc: Worksheet 8.4: Earthquakes (doc-12785)

Complete this digital doc: Worksheet 8.5: Plotting earthquake activity (doc-12786)

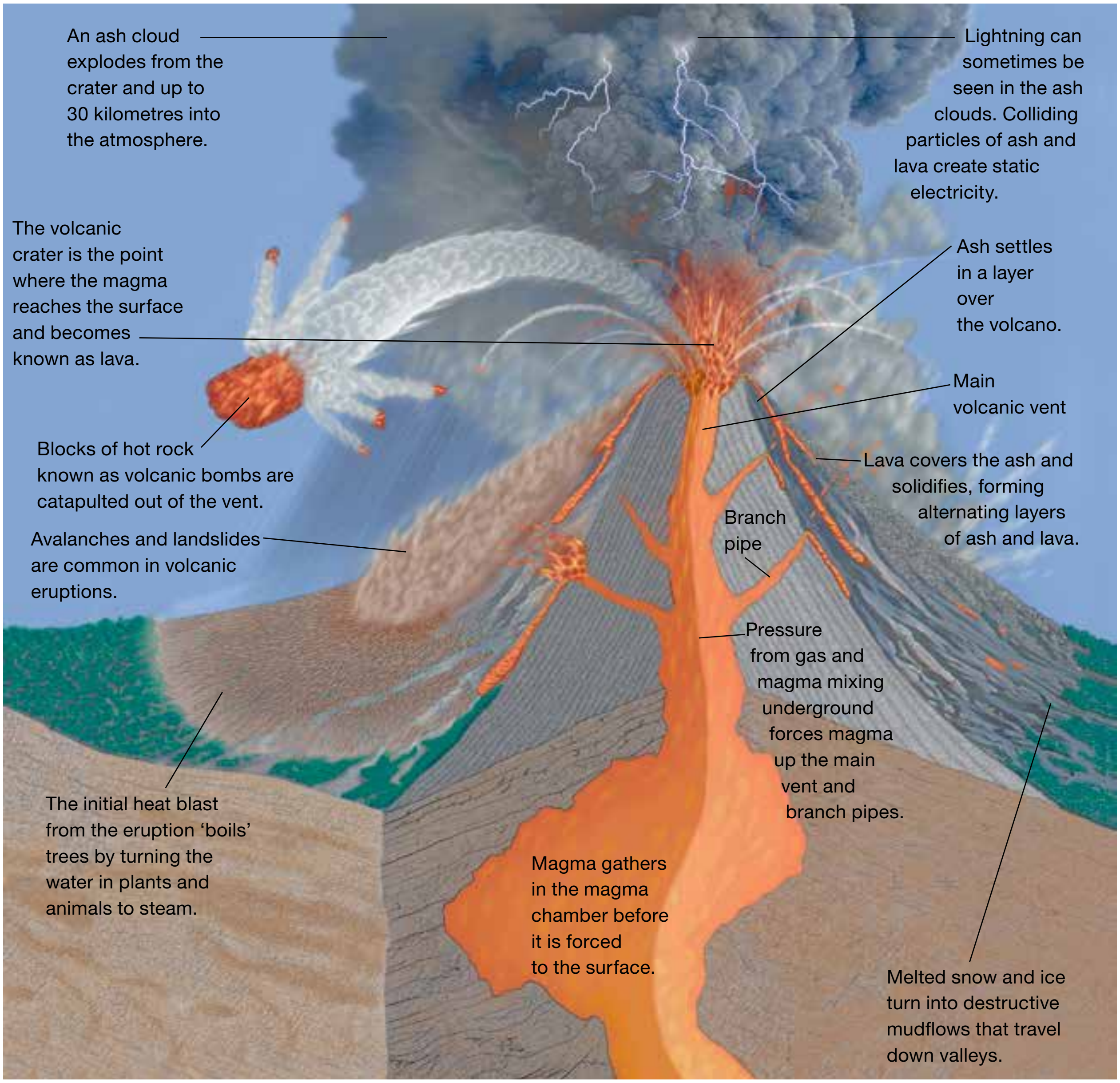
8.6 Mountains of fire

8.6.1 How volcanoes form

A volcano forms when molten rock and gases from the mantle are able to escape onto the Earth's surface. This can occur when weak regions of the crust give way as the result of pressure exerted from the mantle or in regions near plate boundaries.

When these weak areas collapse, a vent (tunnel) or a **fissure** (crack) is formed. **Magma**, made of molten rock combined with dissolved gases, moves up into these vents because it is less dense than the solid rock that surrounds it. When the magma first moves up through the weak region, it forms reservoirs in the

Earth's crust. These are called **magma chambers**. From the vent, the magma is ejected onto the surface in an event called an **eruption**. Once on the surface the molten rock (now called **lava**) starts to cool. Vent eruptions tend to form typical cone-shaped mounds. Flow from a fissure, on the other hand, tends to create ridges either side of the gap. Mid-oceanic ridges are formed from the fissure or vent eruptions of undersea volcanoes.



8.6.2 What comes out?

As the pressure builds up in the magma chamber, ash and steam emerge from the vents of a volcano. When the volcano erupts, lava (a mixture of magma and gases, including steam, carbon monoxide and hydrogen sulfide) flows from the vents and red-hot fragments of rock, dust and ash, steam and other gases shoot out of the crater. Exploding gases often destroy part of the volcano. The larger fragments of rock blown out of the crater are called **volcanic bombs**.

The lava flowing from a volcano can be runny like a milkshake or pasty like toothpaste. If it is runny, it can flood large areas, cooling to form large basalt plains like those in Victoria's western district, in Melbourne, and to the city's north and south.

Thick, pasty lava builds up on the sides of volcanoes and can also block the vents as it cools. When this happens, gases build up in the magma below. As the pressure increases, the volcano can bulge and 'blow its top', thrusting rocks, gases and hot lava high into the air.

8.6.3 Types of volcanoes

With each eruption from a vent, layers of lava, rock, gas and ash flow out over those left behind by previous eruptions, causing a cone to form. Cone volcanoes can be classified according to the steepness of their sides and the material of which they are made. Scientists who study the formation and eruption of volcanoes are called **vulcanologists**.

Shield cones

Shield cones are shaped like low domes and are made from layers of basalt that formed from very fluid, fast cooling lava. This lava is really runny so gases can easily escape it. As a result, shield volcanoes tend not to have explosive eruptions. The sides of shield volcanoes are very gentle. Despite their subtle shape, shield cones can be very large. The largest volcano on Earth is Mauna Loa (Hawaii) which is a shield volcano that is 96 km long and 48 km wide, and rises to a height of 9 km above the ocean floor!

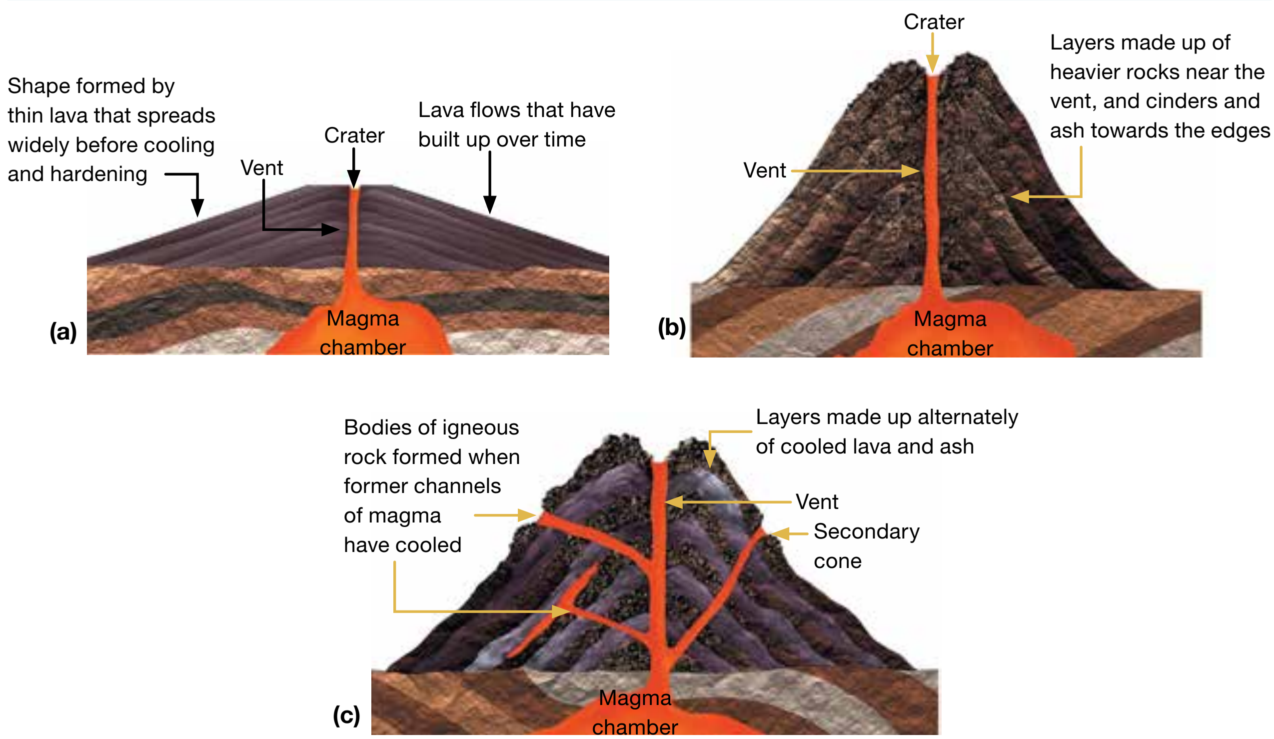
Cinder cones

As their name implies, cinder cones have a very regular pointed shape. Their slopes are steeper than those of shield volcanoes. However, they do not get as large and you would rarely see a cinder cone more than 500 m in height. They are made almost entirely of **pyroclastic material** (ejected material such as cinders, ash and volcanic rocks) and are formed after only a few periods of eruption.

Composite cones

Most volcanoes form composite cones. These have very steep sides and are made of alternating layers of lava and pyroclastic material.

Three different types of volcano: (a) shield, (b) cinder cone and (c) composite.



INVESTIGATION 8.6

Making volcanoes

AIM: To investigate how the size of particle of which a volcano is made affects the slope of its sides

You will need:

a sheet of A2 paper or cardboard
ruler
a large wooden blackboard protractor
4 plastic cups each filled level to the top of the cup with one of the following: coarse sand, gravel, ground chalk dust, soil

- Copy the following data table into your notebook in which to record your results:

Particle	Angle of slope	Diameter of base
Gravel		
Sand		
Soil		
Chalk dust		

- Place the cardboard sheet on your bench and mark an X in the centre with your pencil.
- Take the cup of gravel and hold it about 20 cm above the X on the paper. Carefully tip the cup allowing the gravel to pour onto the X. As the cup gets emptier, you will need to tilt the bottom up higher; it is important while you are pouring that you use as smooth a movement as possible without shaking the cup.
- The gravel will have formed a vaguely conical pile. Beyond the pile, position the board protractor with its bottom edge flat on the bench and held as vertically as possible. Place your eyes at the level of the pile's base and move the protractor so that you can determine the angle at which the pile's side slopes — this is called the angle of repose. Note the angle in the second column of your data table.
- With your pencil use two small crosses on the cardboard to indicate the maximum width of the pile's base. Carefully pour the gravel off the cardboard back into the cup, then use your ruler to measure the distance between the two crosses. Enter this in the third column of your data table, and erase the pencil marks from the cardboard.
- Repeat these steps for the sand, soil and chalk dust.

Discussion

1. Using your data table results, construct a bar graph showing the slope angle (in degrees) of each particle pile.
2. Describe the general relationship between the particle size and the angle slope of the pile that it naturally forms against gravity.
3. Based on this, would you expect an ash cone or a cinder cone to have (a) the steepest sides (b) the largest diameter of base? Explain your answer.
4. Which of these particle piles was shaped the most like a shield volcano?

INVESTIGATION 8.7

Plotting volcanoes

AIM: To find where active or recently active volcanoes are located

You will need:

a map of the world

- The latitude and longitude data on the next page show the location of active or recently active volcanoes. Mark them on your map with small crosses.

- Is there a pattern to the location of volcanic action? If so, describe the pattern in words.

Longitude	Latitude
45°E	12°N
160°E	55°N
120°W	35°N
130°E	5°S
15°E	35°N
15°W	35°S
160°W	55°N
105°E	10°S
25°W	65°N
150°W	15°N
120°E	10°N
25°E	35°N
150°E	10°S
180°E/W	30°S
15°W	30°N
90°W	0°
65°W	15°N
32°E	2°N
150°E	25°N
70°W	40°S
30°W	60°S
175°E	40°S
95°E	5°N
32°W	42°N
150°W	57°N
135°E	37°N
75°W	0°
105°W	20°N
90°W	15°N

8.6.4 Birth of a volcano

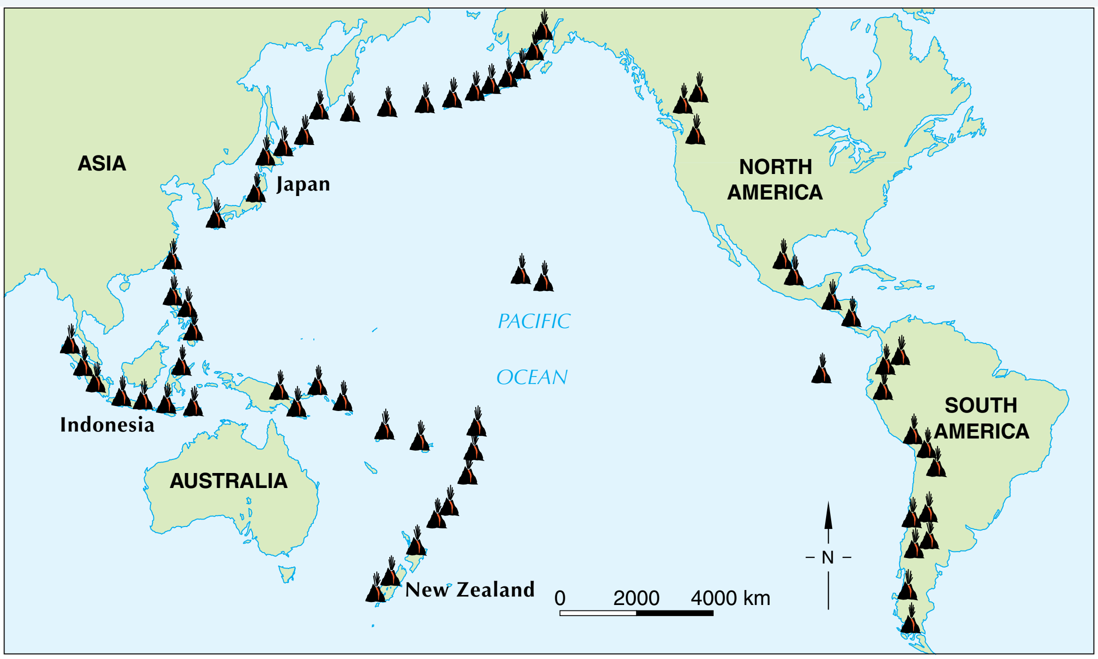
On a cool winter's day in 1943, a small crack opened up in a field of corn on a quiet, peaceful Mexican farm. When red-hot cinders shot out of the crack, the shocked farmer tried to fill it with dirt. The next day, the crack had opened up into a hole over two metres in diameter. A week later, the dust, ash and rocks erupting from the hole had formed a cone 150 m high! Explosions roared through the peaceful countryside and molten lava began spewing from the crater, destroying the village of Paricutin. The eruptions continued and, within a year, the new mountain, named Paricutin, was 300 m high. When the eruptions stopped in 1952, Paricutin was 410 m high.

Paricutin, a new volcano in Mexico. It began as a small crack in a field of corn.

8.6.5 The Ring of Fire

The majority of active volcanoes lie along the perimeter of the Pacific Plate, forming a continuous path through Japan, Indonesia, New Zealand, Hawaii and Alaska, then down along the western coasts of North and South America. Due to the enormous amount of seismic and volcanic activity that occurs along this circuit, it is called the *Ring of Fire* by seismologists. The subduction zones and heavy faulting that occur at the boundary of the Pacific Plate cause the instability seen in these regions.

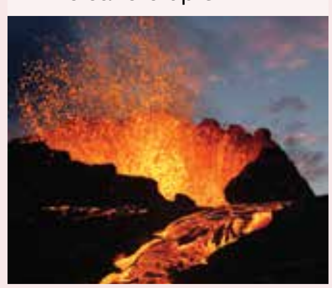
The Ring of Fire



HOW ABOUT THAT!

When Krakatoa in Indonesia blew its top in 1883, the explosion could be heard over 4000 km away. The tsunami caused by the explosion drowned about 36 000 people.

A volcano erupts



8.6.6 Australia's volcanic past

Despite the popular misconception that there are no volcanoes in mainland Australia, young volcanic rocks are widespread in the eastern states. Aboriginal people were probably witnesses to the volcanic activity in Australia, especially in the Mount Gambier area of South Australia around 4300 years ago. Aboriginal stone tools have been found in Victoria buried beneath volcanic deposits.

A belt of recent volcanism (that is, any phenomena associated with volcanoes and volcanic activity) occurs down the eastern states, starting in the Torres Strait and stretching down to the Victorian–South Australian coastline. This volcanism can be divided into two broad types — **central volcanoes** and **lava fields**.

Central volcanoes

Central volcanoes are any phenomena associated with volcanic activity, both past and present, that are not lava fields. The remains of central volcanoes were produced from either a single central vent or a cluster of vents. The largest Australian central volcano is the Tweed volcano. Mount Warning in New South Wales is the Tweed volcano's remaining hard central vent. Other remains of central volcanoes include the Glasshouse Mountains in Queensland and the Warrumbungles in New South Wales.

The youngest volcano in Australia, Mount Gambier, first erupted about 4300 years ago. Its most recent eruption occurred only 1400 years ago. The cone of the Mount Gambier volcano has filled with water to form a **crater lake**. The lake displays a deep blue colour on sunny days, and is a popular tourist attraction.

Lava fields

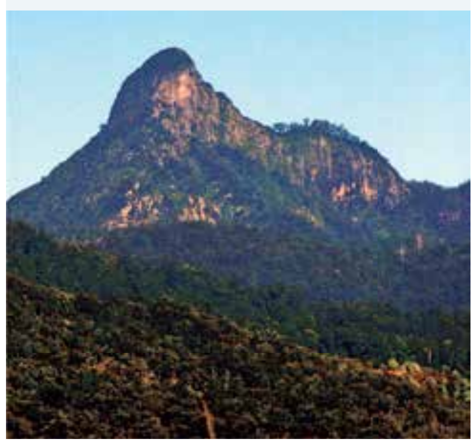
These are areas over which large amounts of basaltic lava have flowed. The lavas are normally very thin and now cap ridge and mountain tops. Lava fields can be found right along the eastern side of Queensland, New South Wales, Victoria and Tasmania. The remnants of one of the most extensive sequences of basaltic lava flows in the world are found in the East Kimberley region of Western Australia. These are very old (about 530 million years) and cover an area of 35 000 square kilometres.

Mount Fox in Ingham, Queensland, was formed by an extensive lava field.

8.6.7 Land ahoy!

Active volcanoes also erupt under the sea. An active volcano below the sea is generally not visible. If layers of lava build up, however, they may eventually emerge from the sea as a volcanic island. Lord Howe Island, off the coast of New South Wales, was formed in this way about 6.5 million years ago. A more recent example is the island of Surtsey, which emerged from the sea off the coast of Iceland in 1963.

Mt Warning is an extinct volcano in far north-eastern New South Wales.



8.6.8 Dead or alive?

Volcanoes that are erupting or have recently erupted are called **active** volcanoes. Mount Pinatubo in the Philippines, which erupted in June 1991 killing 300 people, is an active volcano. There was so much smoke and ash coming from Mount Pinatubo that the Earth's weather was slightly cooler for over a year because clouds of volcanic particles and dust blocked out 4 per cent of the sun's light!

Extinct volcanoes are those that have not erupted for thousands of years. They are effectively dead and are most unlikely to erupt again. There are many extinct volcanoes in Australia. The Glasshouse Mountains of Queensland are the remains of cooled lava trapped in the central vents of volcanoes. There are many extinct volcanoes in Victoria. Tower Hill, near Warrnambool, is just one example, and there are many others just to the north of Melbourne. Unfortunately, there have been cases where a volcano has been thought to be extinct, but revealed to have been merely dormant after it erupted with devastating results.

Volcanoes that have not erupted for over 20 years and are not considered to be extinct are called **dormant** volcanoes. Dormant means 'asleep' and these volcanoes could 'wake up' at any time and erupt. Mount Pinatubo was a dormant volcano before its eruption in 1991.

HOW ABOUT THAT!

Perhaps history's most famous eruptions occurred in 79 AD when Mt Vesuvius buried the cities of Pompeii and Herculaneum under 20 metres of ash and molten rock. Forgotten for centuries, Pompeii was rediscovered in 1599 and extensive excavation of the site began in the 18th century. The diggers found a number of hollow 'voids' between ash layers. When filled with plaster, these voids were revealed to be hollow moulds of the bodies of the eruption's victims. While archaeologists once theorised that the Pompeiians had been suffocated by ash and toxic gases, a study in 2010 revealed that it was more likely that they were killed by temperature surges which heated the air to 250 °C. Even those people sheltering in buildings would have died instantly.

8.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** what causes a volcano to erupt.
2. **Distinguish** between a dormant volcano and an extinct volcano.
3. **Explain** the difference between magma and lava.
4. **Recall** what materials emerge from a volcano's crater during an eruption.
5. How do shield, cinder cone and composite volcanoes differ from each other? What is pyroclastic material? Give at least two examples.

Think

6. Should Mount Gambier be described as an extinct or dormant volcano? **Explain** your answer.
7. **Explain** how a volcano can affect the world's weather.
8. **Construct** a Venn diagram to show the differences and similarities between central volcanoes and lava fields.
9. **Describe** how you can tell if the volcanoes in your district had runny lava when they were active.

Create

10. Write a short story about an underwater volcano entitled 'The birth of an island'.
11. Collect newspaper articles about volcanic eruptions that have occurred recently. **Construct** a poster to display the articles in your classroom.
12. **Construct** a papier-mâché model volcano. Shape some chicken wire into a cone with a small crater at the top. Soak small pieces of newspaper in a pasty mixture of flour and water and attach the sticky newspaper to your wire cone. You will need to apply several layers of newspaper. Use colour to brighten your model.
13. Imagine that you are the Mexican farmer who found the crack in the ground that gave birth to the volcano Paricutin. Write an account of what you saw and how you felt during the week after you first found the crack in the ground.

14. The five most dangerous eruptions in history (so far) are shown in the following table.

Location	Date	Casualties
Tambora (Indonesia)	1815	92 000
Santorini (Greece)	1628 BCE	Minoan civilisation
Krakatoa (Indonesia)	1883	36 400
Santa Maria (Guatemala)	1902	6000
Mt St Helens (US)	1980	57

Construct a timeline drawn to scale showing when these eruptions occurred.

Investigate

15. Find out the name and location of a dormant or extinct volcano that is close to your school.
16. Two of the most famous volcanoes in the world are Mount Vesuvius and Mount Krakatoa. **Investigate** where they are, when they erupted and what damage they caused.
17. Write an account of a recent major volcanic eruption. Some that you might choose from are:
    - Mount Ruapehu, New Zealand, 1994 and 1996
    - Mount Tavurvur, Papua New Guinea, 1994
    - Eyjafjallajoökull, Iceland, 2010.

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Complete this digital doc: Worksheet 8.6: Volcanic activity (doc-12787)

8.7 Project: Disaster-proof

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8.7.1 Scenario

Earthquakes occur when pressure built up between adjacent sections of rock in the Earth's crust is suddenly released. The bigger the earthquake's magnitude, the greater the amount of energy that shakes the Earth. Solid ground seems to move like water, roads crack, buildings fall and people die. However, the magnitude of the earthquake is not necessarily a good indication of how deadly it will be. The May 2006 earthquake in Java had a magnitude of 6.2 and caused the deaths of nearly 6000 people, yet the 2004 Guadalupe earthquake was the same size but killed only 1 person. In some cases, magnitude 5.3 earthquakes have killed more people than those with magnitude 8.1. In fact, one of the key predictors other than magnitude of how deadly an earthquake in an area will be is how heavily populated the area is and what type of buildings are there. It is a sad fact that the majority of people who die in earthquakes do so because the buildings around them fail.

While Australia is not near a plate boundary, as the more earthquake-prone regions of the world are, we are not out of danger. The 1984 Newcastle earthquake had a magnitude of 5.6 and resulted in 13 deaths, 160 injuries and damage to over 60 000 buildings. With this in mind, your company — Shakeless Seismic Solutions — has been approached by a wealthy client who suffers from acute seismophobia. She wishes to build a five-storey office block in Perth and she wants it to be as earthquake-proof as possible. However, yours is not the only company that she has approached. In order to determine which business she will award the contract to, she is asking each company not only to come up with a design, but also to have a scale model of their design tested on a shake-table earthquake simulator.

8.7.2 Your task

Your group will use research, ingenuity and online simulators to design a five-storey office block that will survive an earthquake. You will build a scale model of your design and compete with other groups to determine which model/design is able to withstand the most energetic shaking on the simulator and so which company will win the building contract. Your model will need to fulfil the following criteria:

- It should have a total mass of no more than 1.5 kg.
- It should have a base area no bigger than 20 cm × 20 cm and should have a height of at least 50 cm.
- No glue, staples, nails or pins are allowed to be used; however, you may use interlocking pieces.
- It must be freestanding (it may not be stuck to the table in any way).

Before testing, you will be required to explain the main aspects of your design to the client (your teacher) and describe what makes the model and the real building earthquake-proof.

8.7.3 Process

- Start your research. Make notes about information that you think will be relevant to your project, including what factors determine a building's stability in an earthquake. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopedia) to help you discover extra information about earthquakes and how they affect buildings.
- Use what you have learned to build your model for test day.

8.8 Review

8.8.1 The theory of plate tectonics

- **explain** Wegener's theory of continental drift — 8.2
- **describe** the use of scientific ideas and technology in the development of the theory of plate tectonics — 8.3
- **describe** what Pangaea was and recall when it existed — 8.2
- **describe** the Earth's crust and compare it with other layers below and above the Earth's surface — 8.2, 8.3
- **describe** evidence supporting the theory of plate tectonics, including the location of volcanic activity and earthquakes — 8.2, 8.3
- recognise the major plates on a map of the Earth — 8.3
- **explain** the movement of plates in terms of heat and convection currents in the Earth's mantle — 8.3
- **describe** and compare the processes of subduction and the formation of ocean ridges — 8.3
- model the process of subduction and sea-floor spreading — 8.3
- **explain** how the Himalayas were formed — 8.2, 8.3

8.8.2 Folding and faulting

- **describe** and model the processes of folding and faulting — 8.4
- **describe** the three main types of fault — 8.4
- **describe** the difference between a syncline and an anticline — 8.4
- relate folding to the movement of tectonic plates and the formation of mountain ranges — 8.4
- **explain** the formation of faults in terms of the forces acting within the Earth's crust and the movement of plates relative to each other — 8.3, 8.4

8.8.3 Earthquakes and tsunamis

- relate the occurrence of major earthquakes and volcanoes to the movements along plate boundaries — 8.5, 8.6
- **compare** the energy released by earthquakes with different values on the Richter scale — 8.5
- associate tsunamis with earthquakes and volcanic activity — 8.5, 8.6

8.8.4 Volcanoes

- **identify** the main features of a volcano — 8.6
- **distinguish** between lava and magma — 8.6
- **recall** how volcanoes may form and in what regions they are most likely to be found — 8.5, 8.6
- **describe** and compare the characteristics of active, dormant and extinct volcanoes — 8.6
- relate the age and stability of the Australian continent and its lack of volcanic and major earthquake activity to its location away from plate boundaries — 8.3, 8.4, 8.5, 8.6

8.8.5 Science and society

- **describe** the role of seismologists and vulcanologists in the investigation of the Earth's crust — 8.4, 8.5, 8.6
- **explain** the importance of early warning systems to people living near plate boundaries, particularly on the edges of the Pacific Ocean — 8.5

Individual pathways

ACTIVITY 8.1
Revising the dynamic Earth
doc-10659

ACTIVITY 8.2
Investigating the dynamic Earth
doc-10660

ACTIVITY 8.3
Investigating the dynamic Earth further
doc-10661

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FOCUS ACTIVITY

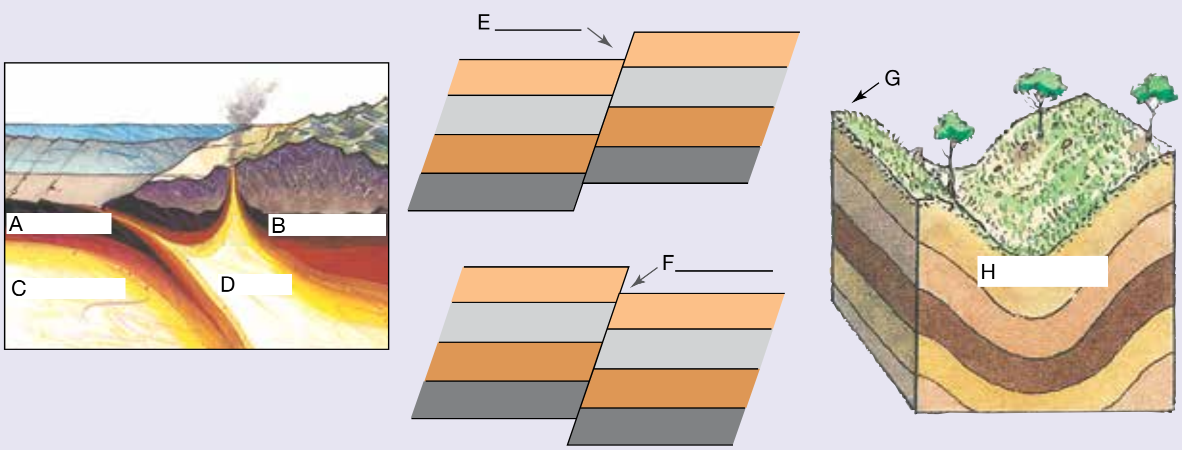
Read the article ‘How a supervolcano covers a continent’. Use the information in the article to answer questions.
Access more details about focus activities for this topic in the Resources tab (doc-10658).

8.8 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What evidence supports the theory of plate tectonics?
2. What is continental drift?
3. **Describe** how the Earth’s layers formed.
4. **Describe** how an extinct volcano is different from an active volcano.
5. **Identify** where on Earth you would find the Ring of Fire and explain how it got its name.
6. According to the theory of plate tectonics, the Earth’s crust is divided into a number of slowly moving plates.
   (a) **Explain** what makes the plates move.
   (b) **Describe** what can happen when two plates slide past each other.
   (c) How does the theory of plate tectonics explain the increasing height of the Himalayas?
7. **Distinguish** between an ocean ridge and a subduction zone.
8. **Explain** why the oceanic crust slides underneath the continental crust when one pushes against the other.
9. **Describe** the movements in the Earth’s crust that cause the folding of rock that has shaped most of the Earth’s mountains.
10. Suggest at least two reasons why an earthquake that registers 6.6 on the Richter scale can cause more deaths and devastation than an earthquake that registers 7.9 on the Richter scale.
11. **Identify** what a seismograph measures and explain how it works.
12. How are S-waves different from P-waves?
13. **Identify** each of the features labelled A–H.



14. Which type of seismic wave causes most of the damage during an earthquake?
15. **Explain** how regions that are not near plate boundaries can experience earthquakes.
16. **Recall** at least three substances that are likely to be ejected from a volcano when it erupts.
17. **Identify** the following.
   (a) The single supercontinent that dominated the Earth 225 million years ago
   (b) The sea that surrounded Pangaea
   (c) The two continents that were separated by the Tethys Sea 200 million years ago
   (d) The present day continents that made up the ancient continent Gondwana

18. Folds and faults are caused by movements in the Earth's crust. The movements that cause folding are different from the movements that cause faulting. **Describe** the different movements that cause folds and faults.
19. How are volcanoes formed?
20. Read through the following list. Each feature describes either continental or oceanic crust. Decide which type of crust each feature is describing and transfer it to a table like the one shown below.
    - About 6–8 km thick
    - Made of lightweight rocks, like granite
    - Very old
    - Forms from lava that bursts through cracks under the ocean
    - Between 30 and 70 km thick
    - Made of heavy, dense rocks
    - Forms from volcanic activity, weathering and sedimentation
    - Quite young

Oceanic crust	Continental crust

21. What type of crust is the Pacific Plate made from? **Explain** your answer.
22. The San Andreas Fault makes much of coastal California, including the cities of Los Angeles and San Francisco, susceptible to earthquakes.
    (a) **Explain** why the San Andreas Fault is called a slip fault.
    (b) What causes major earthquakes along this fault?
23. **Distinguish** between the epicentre of an earthquake and its focus.
24. How much more energy is released by an earthquake that registers 6.0 on the Richter scale than by one that registers 7.0 on the Richter scale?
25. Before a volcano erupts, its vents are blocked with thick, pasty lava.
    (a) What change takes place to cause the volcano to erupt?
    (b) How is the lava emerging from a volcano different from magma?

Test yourself

1. Divergence occurs when plates are
   (A) moving away from each other.
   (B) sliding past each other.
   (C) moving towards each other
   (D) breaking in half. **(1 mark)**
2. Mt Warning is an example of a
   (A) fold in rock layers.
   (B) dormant volcano.
   (C) extinct volcano.
   (D) monolith. **(1 mark)**
3. Identify which ONE of the following is NOT true about tsunamis.
   (A) They are the same thing as tidal waves.
   (B) They may be caused by underwater earthquakes.
   (C) They are higher in shallow water than out in the ocean.
   (D) They may travel through the ocean at speeds of up to 800 km/h. **(1 mark)**
4. The movement of tectonic plates is caused by
   (A) earthquakes.
   (B) convection in the mantle.
   (C) the rotation of the Earth on its axis.
   (D) melting ice caps. **(1 mark)**

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Complete this digital doc: Worksheet 8.7: Geological activity (doc-12788)

Complete this digital doc: Worksheet 8.8: The dynamic Earth puzzles (doc-12789)

Complete this digital doc: Worksheet 8.9: The dynamic Earth summary (doc-12790)

TOPIC 9
On the move

9.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

9.1.1 Why learn this?

The thrill of a roller-coaster ride allows you to experience sudden changes in motion. When the car suddenly falls, you seem to be pulled back just for a while. Such a ride raises many questions about the way that forces affect your motion.

LEARNING SEQUENCE

The changes in velocity and acceleration experienced on a roller-coaster can be explained by Newton's laws of motion.

Moving experiences

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. In this topic you will learn about the forces that act on objects as they move. You already use much of the language of force in everyday conversations, and this activity will remind you of what you already know.
   (a) Start by writing what you understand the important terms at right to mean. (Skip any that you find difficult to explain.)
   (b) Once you have written your meanings, share them with a partner. Discuss any meanings that you disagree on.
   (c) Together with your partner, write an interesting account of an event that uses each of the words listed in the box above. For example, you could write from the viewpoint of a pilot on an airplane about the details of your flight so far.
   (d) Share your account with the rest of the class.

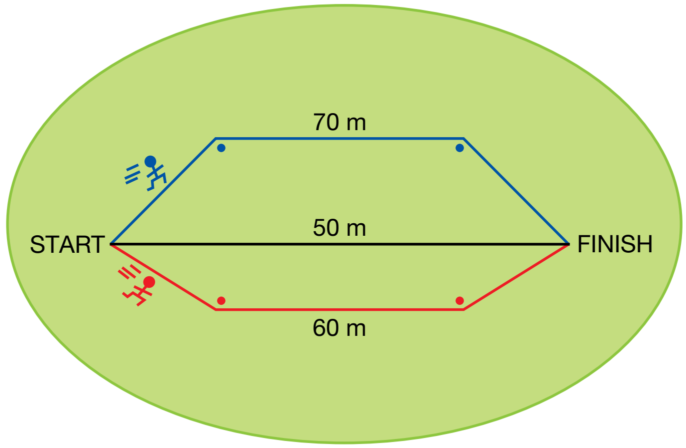
2. Sir Isaac Newton is one of the most famous of our historical figures because of the significant contribution he made to our current scientific understanding of motion. In your group, discuss what you already know about Newton and his discoveries and put your ideas into a mind map.
3. Modern cars are legally required to include safety features such as head restraints, seatbelts and airbags.
   (a) Draw a labelled diagram to explain what happens to your body if a car that you are travelling in stops suddenly.
   (b) Add explanatory labels to your diagram to describe how these safety features can protect you in an accident.
   (c) What other safety features does your car have?
   (d) How do you think that the safety rating of vehicles is determined?
4. (a) The speedometer in your car measures how fast you are travelling. Explain how you think a speedometer works.
   (b) The police are able to detect whether you are travelling faster than the speed limit. Explain how you think the police can measure your speed.
5. Explain why athletes use starting blocks for sprints in competitive races.
6. When cycling on a bike:
   (a) what forces are acting while moving on a flat stretch of road?
   (b) what forces are acting while moving down a hill?
   (c) will peddling harder always result in you speeding up? Explain.
7. What is the difference between acceleration and deceleration?

9.2 How far is it?

9.2.1 Distance and displacement

The coach sounds the whistle and you know it's time to start the warm-up drill. Running across the oval, you wind your way through a course to a finish point marked out by coloured cones. Your team-mate takes a different route through a second set of cones. How do your paths differ and how are they the same?

The diagram at right shows three paths to the end of the oval. Yours is the blue path. Your friend runs along the red path. The black path is the shortest **distance** from the starting point to the finishing point.



The three paths all differ in length, so the distance that you travel is different from that of your friend, and different again from the shortest path. You have travelled 70 m, your friend has travelled 60 m and the shortest path is just 50 m from the starting point.

The shortest distance between the starting and finishing points is called the displacement. The displacement of an object is actually its change in position in a straight line path. Displacement is always given as a length and a direction. The displacement from the starting point in the above example is 50 m to the east.

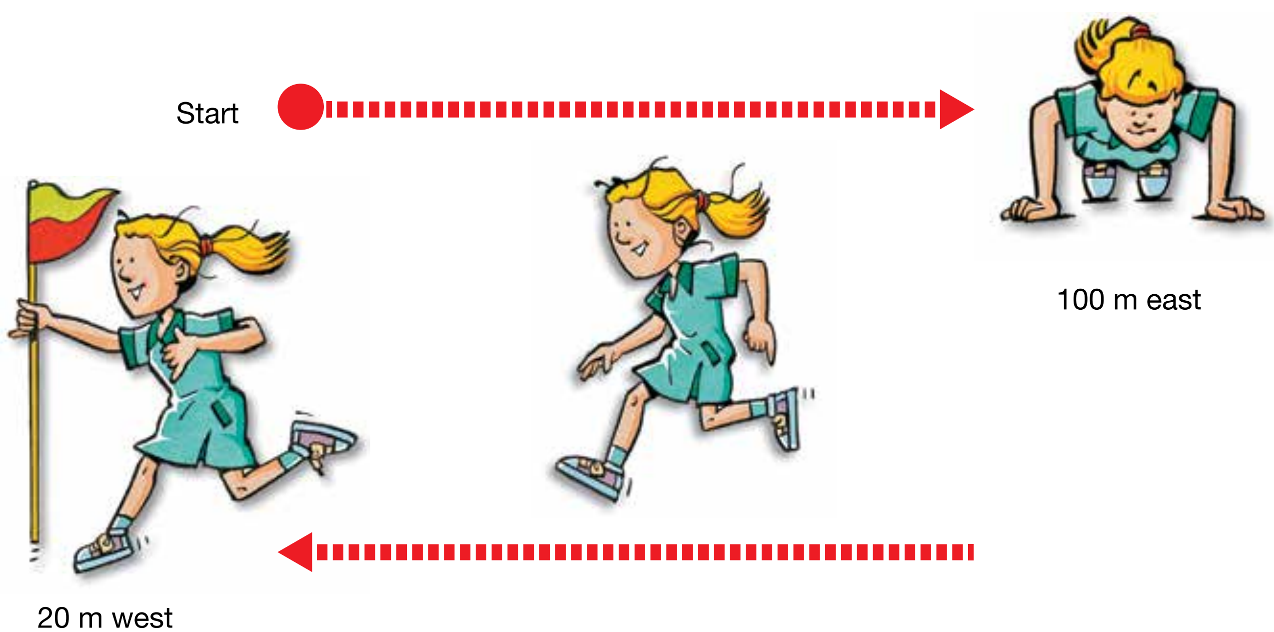
Displacement is an example of a vector measurement, meaning the measurement is expressed as a size and a direction. Displacement tells us only about the starting and finishing points, but nothing about the path in between. In the warm-up drill example, you and your friend both have a displacement of 50 m east from the starting point, even though your paths differed in length. That is because both of you have started and finished in the same place.

The distance that you have covered is an example of a **scalar** measurement. Scalar measurements are expressed only as a size, with no direction. In the above example, your distance is different from your friend's because the actual path is taken into account, not just your starting and finishing points.

9.2.2 Straight line motion

Straight line or linear motion involves an object moving side to side or up and down along a single straight line.

In another training drill you are asked to run back and forth along a straight line; in it you run east 100 m, drop down to complete 10 push-ups, run back to your starting point, and then run west 20 m past your original starting point to collect a flag.



The total distance that you have travelled in this drill is:

$$100 + 100 + 20 \text{ m} = 220 \text{ m}.$$

Your displacement takes into account only your starting and finishing points, and can be stated as '20 m west'. You could use plus (+) and minus (−) signs to indicate direction. If 'east' is taken as the positive direction, your displacement at the end of this drill is written as '−20 m'.

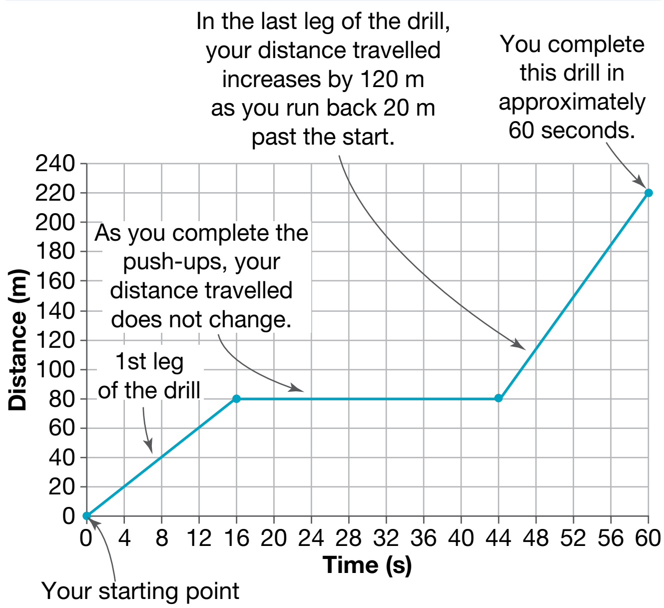
While your total distance is calculated by adding the length of each section that you have travelled along, your displacement is calculated by comparing your finishing with your starting point.

In the above example, if you had later walked back to your starting point, your total distance travelled would have been 240 m and your displacement would be 0. Can you see why?

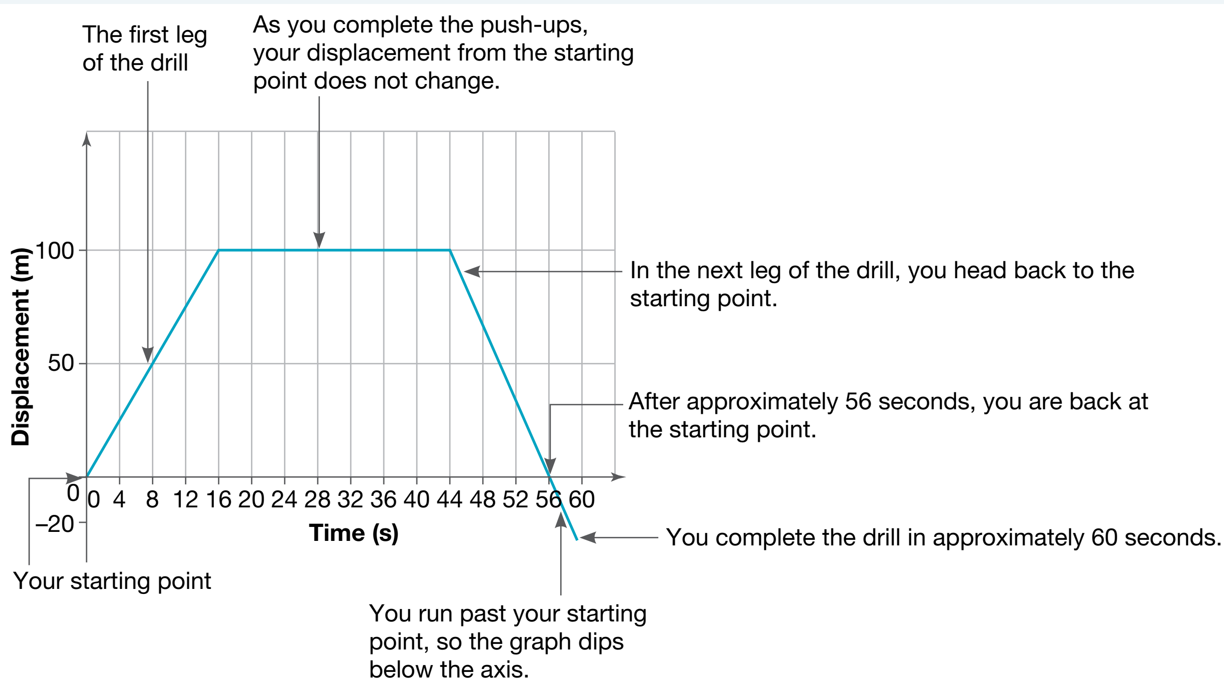
9.2.3 Using a line graph to plot your position

The position throughout your motion can be plotted on a line graph. Your position is plotted on the vertical (*y*-axis) while the time elapsed is plotted on the horizontal (*x*-axis). Such a graph can be used to plot the distance travelled over time or the displacement versus time. Be careful, a distance–time graph may look quite different to a displacement–time graph, even for the same journey.

A distance–time graph for the circuit



A displacement–time graph for the circuit



9.2.4 Parking sensors

Parking sensors are a technology commonly included in cars today. The sensors are embedded in the front or rear bumper bar of a car and measure the distance to nearby objects, warning drivers if there is a risk of collision while moving into a parking spot. The parking sensor works by emitting ultrasound at a frequency around 40 kHz and then measuring the time taken for sound pulses to be reflected back to determine the distance to a car or other obstacle while parking.

Parking sensors detect the distance to nearby obstacles using reflected ultrasound.

HOW ABOUT THAT!

AFL footballers use Global Positioning Satellite (GPS) equipment so that coaches can trackw the movement of players around the field. Each player wears a locator beacon, about the size of a pack of cards, that sits unobtrusively under his jumper. GPS satellites track the position of the players on computers and then analyse their movements. Total distances covered, time spent walking, jogging, running, **average speed**, maximum speed and heart rate are all measured with the unit. Computer software then allows a player's performance to be compared with previous games or against teammates.

A footballer wearing a GPS device

9.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

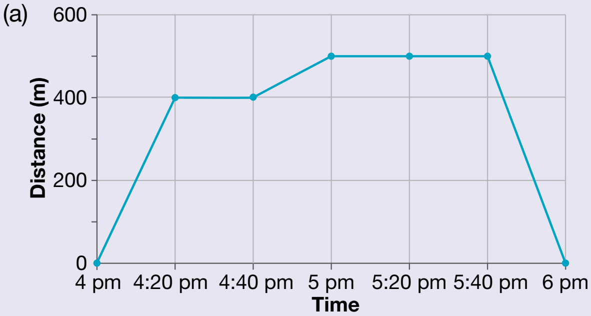
1. **Recall** the difference between distance and displacement.
2. **Describe** how a vector measurement differs from a scalar measurement.
3. **Explain** the purpose of the negative (–) sign in the straight line motion example of the running drill.
4. According to the position–time graphs, **identify** how long it took you to complete the set of push-ups.

Think

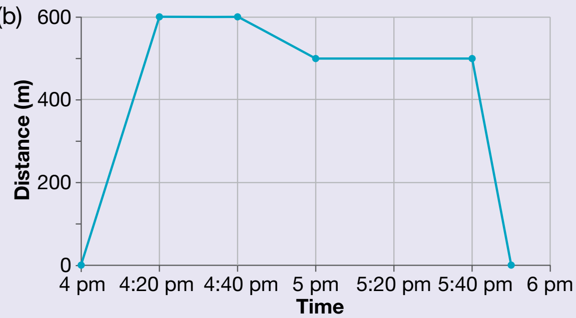
5. In the displacement–time graph, what is your displacement when completing the push-ups?
6. The text describes how, in the running drill, your distance travelled becomes 240 m and your displacement 0 m if you walk back to your starting point. **Explain** why.
7. In a shopping trip, you travel 150 m to the shops and back home again. **Calculate**
   (a) the distance travelled
   (b) the displacement for your journey.
8. According to the distance–time graph, **identify** at what point through the running drill you are travelling the fastest.
9. A dance routine has you take three steps back, shake your hips, take five steps forward and stomp your foot, then take two steps back and shake your head.
   (a) **Construct** a number line to represent the dance steps.
   (b) **Calculate** the distance you travel in steps during the entire dance routine.
   (c) **Calculate** your displacement from the beginning to the end of this dance routine in steps.

10. A student recorded their position from home to the local shops on two separate afternoons and presented this data in the form of line graphs. Refer to each of the graphs at right in describing the journey on each afternoon.

(a)



(b)



Investigate

11. How could the data obtained about the movements of AFL footballers be used by their clubs? **Investigate** the type of ICT application that could best analyse this data.
12. The GPS system was set up and is maintained by the United States military for their own use, although they allow us to access the system. Using the internet, prepare a summary of how these systems operate, how accurately they give a position and the uses for GPS.

learnon RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 9.1: Distance and displacement (doc-12791)

9.3 Ready, set, go!

9.3.1 Average speed

Could a kangaroo win the Melbourne Cup? Who would win a race between a sea turtle, a dolphin and an Olympic swimmer? You can answer these questions only if you know the **average speed** of each 'competitor' during the race.

Speed is a measure of the rate at which an object moves over a distance. In other words, it tells you how quickly distance is covered. The average speed can be calculated by dividing the distance travelled by the time taken. That is:

Who would win?

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}.$$

In symbols, this formula is usually expressed as:

$$v = \frac{d}{t}.$$

9.3.2 Which unit?

The speed of vehicles is usually expressed in kilometres per hour (km/h). However, sometimes it is more convenient to express speed in units of metres per second (m/s). The speed at which grass grows could be sensibly expressed in units of millimetres per week. Speed must, however, always be expressed as a unit of distance divided by a unit of time.

Some examples

(a) The average speed of an aeroplane that travels from Perth to Melbourne, a distance of 2730 km by air, in 3 hours is:

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{2730\text{ km}}{3\text{h}} \\ &= 910\text{ km/h.} \end{aligned}$$

The formula can also be used to express the speed in m/s.

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{2\,730\,000\text{ m}}{3 \times 3600\text{ s}} \text{ (converting kilometres to metres and hours to seconds)} \\ &= 253\text{ m/s} \end{aligned}$$

(b) The average speed of a snail that takes 10 minutes to cross an 80 cm wide concrete paving stone in a straight line is:

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{80\text{ cm}}{10\text{ min}} \\ &= 8\text{ cm/min.} \end{aligned}$$

Units of measure

It is important that scientists can share their data and findings. To do this, they use a common set of units. In 1960, scientists from across the world agreed on a common system known as the **International System of Units (SI)**. The SI unit for both distance and displacement is the metre (m) and the SI unit for speed and velocity is metres per second (m/s).

You may have seen 'metres per second' also written as 'ms^{-1}'. These units are derived from the formula for calculating speed:

$$\text{speed} = \frac{\text{distance}}{\text{time taken}} = \frac{\text{(metres)}}{\text{seconds}}$$

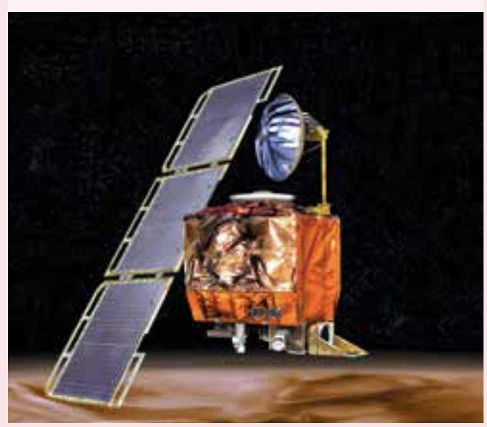
When shifting the 'seconds' from the denominator to the numerator of the fraction, the index (or power) becomes negative. Hence, the seconds are written with an index of -1 in ms^{-1}.

HOW ABOUT THAT!

Confusion over units causes the Mars Orbiter satellite loss

NASA lost the $125 million *Mars Climate Orbiter* because an error was made by the contractor, who used English Imperial measurements (feet, pounds, inches). The Jet Propulsion Laboratory (JPL) navigation team, however, used SI-system measurements in the complex business of calculating the spacecraft's position. When the JPL team said, '500 metres', the spacecraft's computer thought, '500 feet' (about 150 m). The spacecraft went too close to the planet's atmosphere, where it burned and broke into pieces. After completing a 10-month journey to Mars, it was lost on 23 September 1999. 'People sometimes make errors,' said Edward Weiler, NASA's Associate Administrator for Space Science . . .

NASA's *Mars Climate Orbiter*



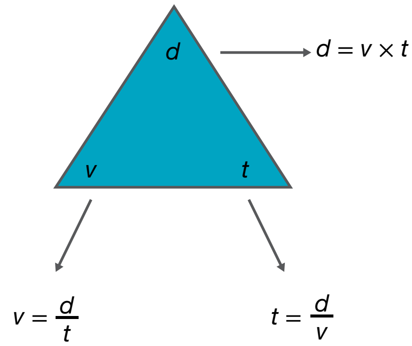
9.3.3 Calculating distance and time

The formula used to calculate average speed can also be used to work out the distance travelled or the time taken.

Since $v = \frac{d}{t}$

$d = vt$ and $t = \frac{d}{v}$.

You might like to use a formula triangle to solve problems using this equation. Place your finger over the variable you wish to calculate:



More examples

(a) The distance covered in $2\frac{1}{2}$ hours by a train travelling at an average speed of 70 km/h is:

$d = vt$

$= 70 \text{ km/h} \times 2.5 \text{ h}$

$= 175 \text{ km}.$

(b) The time taken for a giant tortoise to cross a 6 metre wide

deserted highway at an average speed of 5.5 cm/s is:

$t = \frac{d}{v}$

$= \frac{6.0\text{m}}{0.055 \text{ m/s}}$ (converting 5.5 cm/s to 0.055 m/s)

$= 109$ s (to the nearest second)

$= 1$ min 49 s.

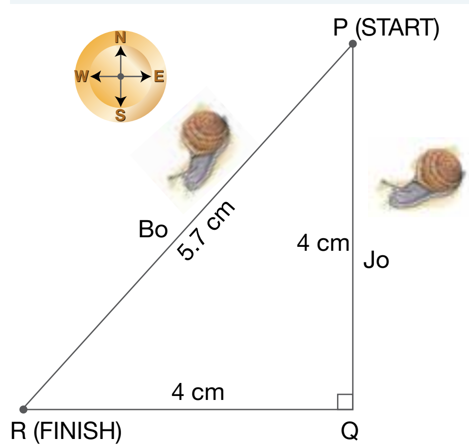
9.3.4 When the direction matters

The term **velocity** is often used instead of speed when talking about how fast things move. However, velocity and speed are different quantities. Velocity is a measure of the rate of change in position (displacement), whereas speed is a measure of the rate at which a distance is travelled. To describe one's displacement, the direction must be stated, so velocity has a direction as well as a **magnitude** (size). When determining speed, the direction of movement does not matter.

Imagine a race between two snails, Bo and Jo, between the points P and R shown in the diagram on the right. Bo, being slower but smarter, takes the direct route. Jo, faster but not as clever, takes an indirect route via Q. The race is a dead heat — both snails finish in 1 minute.

The table on the next page describes the motion of the two snails and shows the difference between their speed and velocity.

A race at a snail's pace



The race between Bo and Jo

	Bo	Jo
Average speed	$\frac{\text{distance travelled}}{\text{time taken}}$ $= \frac{5.7 \text{ cm}}{1 \text{ min}}$ $= 5.7$ cm/min	$\frac{\text{distance travelled}}{\text{time taken}}$ $= \frac{8.0 \text{ cm}}{1 \text{ min}}$ $= 8.0$ cm/min
Average velocity	$\frac{\text{change in position}}{\text{time taken}}$ $= \frac{5.7 \text{ cm}}{1 \text{ min}}$ SW $= 5.7$ cm/min SW	$\frac{\text{change in position}}{\text{time taken}}$ $= \frac{5.7 \text{ cm}}{1 \text{ min}}$ SW $= 5.7$ cm/min SW

Notice that when there is no change in direction, the magnitude of the velocity is the same as the speed.

INVESTIGATION 9.1

Distance and displacement

AIM: To compare the speed and velocity of a journey through the school

You will need:

trundle wheel or smartphone with GPS locator
stopwatch
compass

- With the members of your group, plan the path for a journey from your classroom to the canteen and then to a favourite recreation spot in the playground, preferably without the need to use stairs.
- Begin timing and walk the route. Record the distance travelled using the trundle wheel or GPS locator.
- Record the time taken for the journey.
- Calculate the speed travelled using the equation $v = d/t$ and record your answer in m/s.
- Measure the displacement or change in position as a straight line from the start to the finish point for the journey using the trundle wheel or GPS locator. If this cannot be done because of the obstacles between, estimate this length.
- Calculate the velocity for the journey and record your answer in m/s. Use the compass to determine the direction travelled from the starting point and include this along with the magnitude of the velocity.

Discussion

1. Why were your speed and velocity so different for this journey?
2. Why did your speed exceed your velocity?

9.3.5 Interpreting position–line graphs

The Stawell Gift in Victoria is a famous annual race. This is a handicap event so the starting positions of the competitors are determined by their fastest times in previous race heats. To win the final race, a competitor needs to cross the finish line in the quickest time. As the starting position for each competitor is different, it means that some competitors will have to travel much faster than others in order to win the race. At right is an example of a heat.

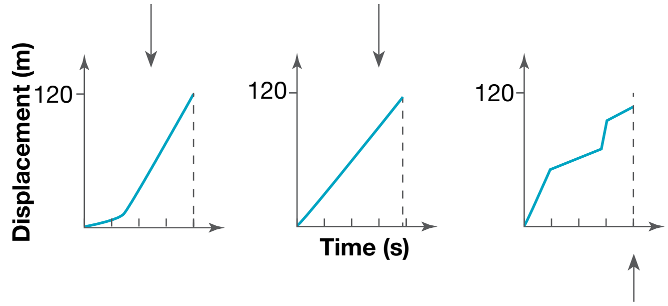
Using the gradient

The slope of a position–time graph tells us how quickly the person or object is moving: the steeper the graph, the greater the speed. The slope of a graph is called its **gradient**. The gradient of a graph is calculated by comparing how much the graph rises with how far it goes across. These two measurements are called the rise and the run of the graph.

In the graph below right the competitor's speed increases from 5.0 m/s to 10.6 m/s after the 2-second mark.

This athlete begins slowly, but then speeds up. He reaches a greater speed than the winner, but comes in second.

This athlete runs at a steady speed throughout the race. He is the winner as he reaches the finish line in the quickest time.



This competitor travels at different speeds at different times. The steepest parts of the graph represent the times when he was travelling fastest. In fact, this runner has the top speed of these three competitors, but maintains it for only short bursts. This competitor runs a shorter distance than the other two.

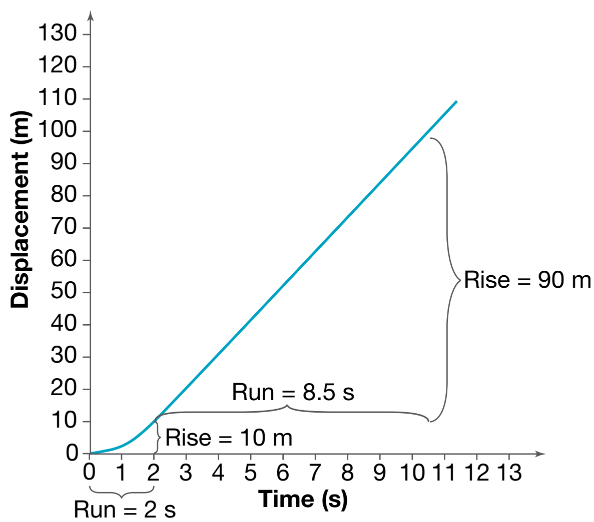
9.3.6 Instantaneous speed

The average speed of an object tells us the overall speed over an entire journey. During that time, the speed may vary from that average. For example, a car that makes a 60-kilometre journey from one side of the city to the other in one hour will have an average speed of 60 km/h. However, this does not mean that the car was travelling at 60 km/h for the entire journey. At some moments in its journey it may have been at rest, or travelling slower than 60 km/h or faster than 60 km/h. The speed of an object at a particular moment in time is called its **instantaneous speed**.

The instantaneous speed of an object may be less than, equal to or even greater than the object's average speed. Consider the graph on the next page, which shows the progress of a 100 m sprinter over the course of her race. As you can see, her average speed in the second half of the race is faster than in the first half. Her instantaneous speed at the 10-second mark is 14.5 m/s, yet her average speed over the entire race is only about 10 m/s.

$$\text{Speed over first 2 seconds} = \text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{10}{2} = 5.0\text{ m/s}$$

$$\text{Speed over next 8.5 seconds} = \text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{90}{8.5} = 10.6\text{ m/s}$$



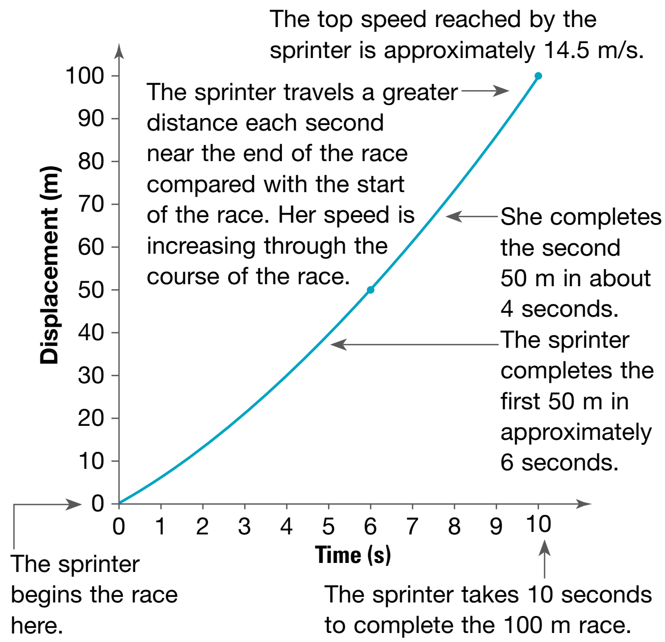
9.3.7 Measuring speed

When German Formula One racing driver Michael Schumacher broke the Australian Grand Prix lap record in 2004, he completed a 5.303 km lap in 84.125 seconds. His average speed was:

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{5303 \text{ m}}{84.125 \text{ s}} \\ &= 63.04 \text{ m/s (about 227 km/h).} \end{aligned}$$

However, he was able to speed down the straight at speeds of up to 320 km/h.

Clearly, the average speed does not provide much information about the speed at any particular instant during the race.



9.3.8 Keeping track of the speed

The full story of each lap of Michael Schumacher's race circuit run could be more accurately told if his average speed was measured over many short intervals throughout the event. For example, if stopwatches were placed at every 100 metre point along the track, his average speed for each 100-metre section of the circuit could then be calculated. On the other hand, if stopwatches were placed every metre along the track, his average speed for each 1-metre section could be calculated. By placing stopwatches at shorter intervals, a more accurate estimate of his instantaneous speed can be obtained.

INVESTIGATION 9.2

Measuring average speed

AIM: To collect distance and time data to plot distance–time graphs

You will need:

tape measure or trundle wheel
stopwatch
calculator

- Form groups of four: one student is the racer and the other three are timekeepers.
- Measure a distance of at least 20 m across the playground and divide it into 3 equal segments; e.g. 10 m each.
- Position a timekeeper at each end of each segment.
- Each timekeeper times how long it takes the racer to cover the distance from the start to the end of their segment. For example, for a 30 m journey, timekeeper 1 records the time taken to cover 10 m, timekeeper 2 records the time taken to reach 20 m, etc.
- Collect time for the racer to:
  – walk the distance
  – run the distance
  each at a steady pace.
- Draw a distance–time graph using the cumulative data for the journey walking and running on the same set of axes. Draw a straight line of best fit for each set of data.

Discussion

1. What is the benefit of plotting results on the one set of axes?
2. In which graph is the line of best fit steepest? What does this indicate?

3. Calculate the gradient of each line to determine the walking and running speed in this experiment.
4. Was the speed walking and running constant for each journey? How do you know?
5. In what time must your racer have covered the distance to be able to compete against an Olympic 200 m runner who has an average speed of 10.4 m/s?

The speedometer inside a vehicle has a pointer which rotates further to the right as the wheels of the car turn faster. It provides a measure of the instantaneous speed.

The police use three different methods to measure the speed of vehicles on the road. These are described below.

- Radar guns and mobile radar units in police cars send out radio waves. The radio waves are reflected from the moving vehicle. However, the frequency of the waves is changed due to the movement of the vehicle. The change in the frequency depends on the speed of the moving vehicle. The altered waves are detected by the radar gun or mobile unit. Radar provides a measure of the instantaneous speed.
- Fixed speed cameras also use radio waves to detect speeding motorists. Electronic detectors are embedded into the road surface in each lane of traffic. As vehicles travel over these detectors, they trigger the emission of radio waves that, when reflected back, allows the speed of each vehicle to be measured. If the speed of the vehicle exceeds the legal limit then a digital picture is taken of the offending vehicle.
- Point-to-point speed cameras are used on various highways throughout the country, particularly in areas identified as road fatality hotspots. They work by measuring the amount of time it takes a vehicle to drive between two points of known distance and then calculating the average speed of the vehicle. Point-to-point cameras record digital photographs of vehicles and their license plate as they pass the start and end points of an enforcement length. The time taken to travel between one camera site and the next and the average speed are then calculated. If the average speed exceeds the speed limit, an infringement notice is issued.

A fixed speed camera

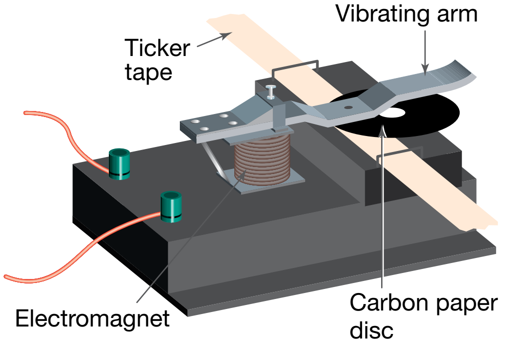
9.3.9 When time ticks away

A ticker timer provides a simple way of recording motion in a laboratory. When the ticker timer is connected to an AC power supply, its vibrating arm strikes its base 50 times every second. Paper ticker tape attached to the moving object is pulled through the timer.

A disc of carbon paper between the paper tape and the vibrating arm ensures that a black dot is left on the paper 50 times every second, leaving a trace of black dots every fiftieth of a second.

The average speed between each pair of dots can be determined by dividing the distance between the dots by the time interval. To make calculating the speed easier, every fifth dot can be marked as shown in the diagram at right.

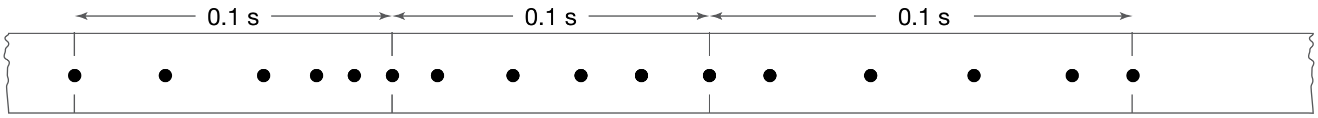
Motion can be recorded with a ticker timer.



Using ticker tape to plot a graph. Each of the marked intervals on the tape represents five-fiftieths of a second — that is, 0.1 seconds. The average speed during the first interval on the tape shown in the figure below is:

$$\begin{aligned} v &= \frac{4.1}{0.1\,\text{s}} \\ &= 41\,\text{cm/s}. \end{aligned}$$

Each marked internal represents a time of 0.1 s.



INVESTIGATION 9.3

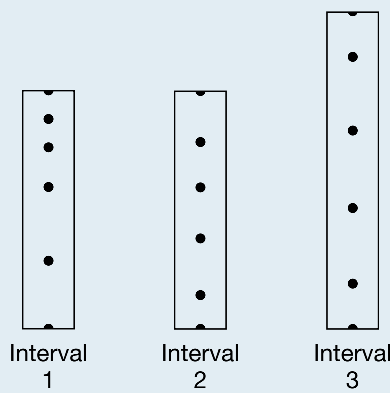
Ticker timer tapes

AIM: To practise using a ticker timer to investigate motion

You will need:

ticker timer
power supply
ticker tape (in 60 cm lengths)
scissors

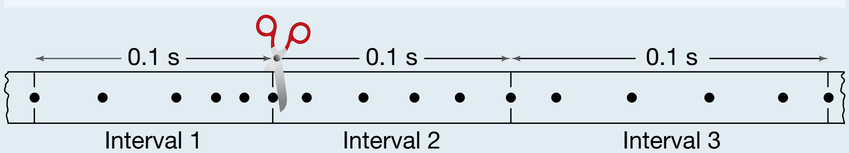
- Connect the ticker timer to the AC terminals of the power supply and set the voltage as instructed by your teacher.
- Thread one end of the ticker tape through the ticker timer so that it goes under the carbon paper disc.
- Hold the ticker timer firmly to the edge of a table or bench so that you will be able to pull approximately 50 cm of ticker tape through it.
- Turn on the power supply and check that the ticker timer leaves a black mark on the ticker tape.
- Hold the end of the ticker tape and pull the ticker tape so that the tape moves through at a steady speed.
- Remove the ticker tape and mark off the first clear dot made and every fifth dot after the first. (There should be four dots between each of the marked-off dots on the ticker tape.) Measure the distance travelled during each 0.1 s interval and write it on your tape. Label the intervals as interval 1, interval 2, interval 3 etc.
- Cut your ticker tape into 0.1 s intervals and glue the strips in order onto a sheet of paper. Glue a maximum of 5 strips. Each strip shows the distance travelled during a 0.1 s time interval. The graph therefore shows how the speed changes with time.



Discussion

1. How much time (in total) elapsed between the printing of the first clear dot and the last dot marked off?
2. Calculate the average speed for the motion that took place between the first clear dot and the last marked dot.
3. Calculate the average speed during each 0.1 s interval.
4. Did you succeed in keeping your speed steady?

Using ticker tape to plot a graph



9.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** the formula used to calculate average speed in symbols and state which quantity each symbol represents.
2. **Explain** the difference between speed and velocity. Use an example to support your explanation.
3. **Describe** how the gradient of a distance–time graph relates to speed.
4. (a) How many times does a ticker timer vibrate each second?
   (b) What is the time interval between consecutive dots on a ticker tape?
5. **Describe** how a fixed speed camera determines the speed of a vehicle on a multi-lane road.

Using data

6. **Calculate** the average speed of each of the following:
   (a) a racehorse that wins the 3200 m Melbourne Cup in a time of 3 min 20 s (in m/s)
   (b) a kangaroo fleeing from a dingo that bounds a distance of 2.5 km in 3 min (in m/s)
   (c) a dolphin that just manages to keep up with a speeding boat for a distance of 2 km for a period of 3 min (in km/h)
   (d) a sea turtle that is able to maintain its maximum speed for 0.5 h, swimming a distance of 16 km (in km/h).
7. **Calculate** how long it would take you to walk from Melbourne to Sydney, a distance of 900 km, if you walked at an average speed of:
   (a) 5 km/h without stopping
   (b) 5 km/h for 10 h each day.
8. **Calculate** how far a snail can crawl if it moves at an average speed of 8.0 cm/min for:
   (a) 3 min
   (b) 3 h.
9. In a heat of a swimming trial an athlete swims the 100 m breaststroke event in 68 s. The event is completed in a pool that is 50 m long. She finishes the event at the same end of the pool from which she started. If she begins the event by swimming due north, and takes 35 s to swim the first 50 m, **calculate** her:
   (a) average speed for the whole swim
   (b) average velocity for the first 50 m
   (c) average velocity for the whole swim.
10. **Calculate** the average speed during the second and third 0.1 s intervals shown in the diagram Each marked internal represents a time of 0.1 s.

Think

11. Is it more important for a police officer's radar gun to measure average or instantaneous speed? **Justify** your answer.
12. If the dots are spaced equally on a ticker tape, **explain** what it suggests about an object's motion.
13. Draw a ticker timer tape that shows an object moving at a decreasing speed.
14. Draw a ticker timer chart that shows an object moving at an increasing speed.

Create

15. Use secondary sources to identify the top speed of a range of native and non-native animals. **Construct** a column graph to compare the speeds of these animals.

Investigate

16. Use a data logger with a motion detector or light gates to record the motion of a toy car. Use the software to produce graphs of distance versus time and speed versus time. **Interpret** the shape of your graphs.

9.4 Speed up, slow down

9.4.1 Acceleration

When a car is stopped at traffic lights and the light turns green, the driver presses the accelerator pedal, causing the car to start moving and then continue to go faster.

Acceleration is a measure of the rate at which an object's velocity changes. You may recall that velocity includes a direction as well as the speed so the definition of acceleration can be given as the rate of change of speed or direction.

The bigger the acceleration, the faster that the speed or direction of an object increases.

Consider the two cars A and B, moving off after pausing at a stop sign.

Time (s)	Speed of car A (m/s)	Speed of car B (m/s)
0	0	0
1	1	2
2	2	4
3	3	6
4	4	8
5	5	10

We can see that the speed of car A is increasing by 1 m/s each second that it is accelerating. We say, then, that car A is accelerating at a rate of 1 m/s per second. In physics this unit is abbreviated to m/s^2. Car B, on the other hand, is accelerating at 2 m/s^2, so it is accelerating faster than car A. Of course, in real life, cars don't accelerate at a constant rate like the cars in our table, so we use average acceleration to describe the increase in velocity. The average acceleration of an object travelling in a straight line can be calculated by dividing the change in velocity by the time taken for the change.

We can write this in the form of an equation:

$$\text{Average acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}.$$

For an object travelling in a straight line, the direction is not changing so the equation can be simplified to:

$$\text{Average acceleration} = \frac{\text{change in speed}}{\text{time taken}}.$$

If the speed is increasing, the acceleration is positive. If the speed is decreasing, the acceleration is negative and is called deceleration.

9.4.2 Fast starters

The sport of drag racing is a test of acceleration. From a 'standing start', cars need to cover a distance of 400 metres in the fastest possible time. To do this, they need to reach high speeds very quickly. The fastest drag racing cars can reach speeds of more than 500 km/h (139 m/s) in less than 5 seconds.

The average acceleration of a drag racing car that reaches a speed of 140 m/s (about 504 km/h) in 4.8 seconds is:

$$\begin{aligned} a &= \frac{\text{change in speed}}{\text{time taken}} \\ &= \frac{(140 - 0)}{4.8} = 29.2 \text{ m/s}^2. \end{aligned}$$

9.4.3 Slowing down

Once the drag racing car has completed the required distance of 400 metres, it needs to stop before it reaches the end of the track. The fastest cars release parachutes so that they can stop faster. The acceleration of a car that comes to rest in 5.4 seconds from a speed of 140 m/s is:

$$a = \frac{(0 - 140)}{5.4} = -25.9 \text{ m/s}^2.$$

As this is a negative acceleration, we say that the drag car is decelerating at 25.9 m/s^2.

Turning corners

If you turn a corner while driving and manage to do so travelling at a constant speed of say 40 km/h, are you accelerating? You would think not because your speed is constant, but remember, acceleration is defined as a change in speed or direction. So, if your direction is changing you are accelerating, even if your speed remains the same.

INVESTIGATION 9.4

Drag strips

AIM: To investigate acceleration using a ticker timer

You will need:

ticker timer
power supply
ticker tape (in 50 cm lengths)
toy car (or dynamics trolley)
sticky tape or masking tape
clear length of bench at least 50 cm long

- Connect the ticker timer to the AC terminals of the power supply and set the voltage as instructed by your teacher.
- Thread one end of the ticker tape through the ticker timer so that it goes under the carbon paper disc.
- Attach the end of the ticker tape to the toy car or trolley.
- Clamp the ticker timer firmly to the edge of a table or bench so that approximately 50 cm of ticker tape can be pulled through it.
- Turn on the power supply and check that the ticker timer leaves a black mark on the ticker tape.
- Model a drag racing car by pushing the toy car or trolley forward, starting from rest, so that it reaches a maximum speed near the halfway mark. Make it come to a gradual stop near the end of the 'track'.
- Remove the ticker tape and mark off the first clear dot and every fifth dot after the first. Each interval between the marks represents a time of $\frac{5}{50}$ of a second, that is, 0.1 seconds. Measure the distance travelled during each 0.1 second interval and write it on your tape. Label the intervals as interval 1, interval 2, interval 3 etc.
- Construct a table like the one below in which to record your data. Calculate the average speed during each interval and record it in the table.
- Now cut your ticker tape into 0.1 second intervals and use the strips as described in Investigation 9.3, to construct a graph of speed versus time.

Discussion

1. Describe the motion of the toy car or trolley during the period over which it was recorded. Ensure that the words 'speed', 'accelerated' and 'decelerated' are used in your description.
2. Between which intervals was the acceleration:
   (a) positive
   (b) negative?
3. During which interval did the greatest average speed occur?
4. When did the greatest positive acceleration take place?

Interval	Distance travelled (cm)	Average speed (cm/s)
Example	3.6	$\frac{3.6\ cm}{0.1\ s} = 36$
1		
2		
3		

9.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

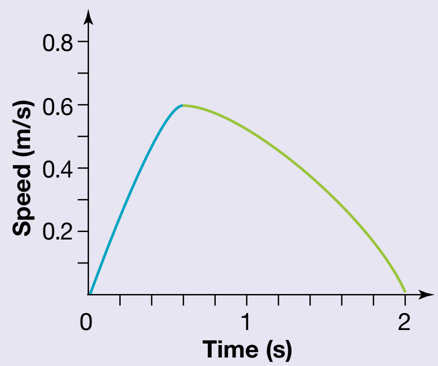
1. **Explain** why the accelerator pedal in a car is called by this name.
2. **Distinguish** between acceleration and deceleration.
3. While on a roller-coaster, you turn a loop at a constant 20 km/h. Are you accelerating? **Explain**.

Think

4. A car that has stopped at a set of traffic lights 'takes off' when the lights turn green. It increases its speed by 5 m/s during each of the first 3 s after it takes off, and by 3 m/s during the following 2 s.
   (a) **Calculate** the speed of the car after:
      (i) 1 s
      (ii) 2 s
      (iii) 5 s.
   (b) **Calculate** the average acceleration of the car during the first 5 s after it takes off.

Using data

5. The 'Drag strips' experiment in Investigation 9.4 was repeated using data-logging equipment and a motion detector, and a graph of speed versus time was produced as shown at right. The blue line indicates the part of the graph where the car was speeding up; the green line indicates where the car was slowing down again. Use the graph to answer the following.
   (a) **Identify** the maximum speed of the car.
   (b) **Identify** at what time the maximum speed was reached.
   (c) **Describe** in what way(s) your graph would be different if the car sped up more quickly, yet reached the same maximum speed.
   (d) **Calculate** the average acceleration of the toy car in the graph while it was speeding up.



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Complete this digital doc: Worksheet 9.2: Acceleration (doc-12792)

9.5 Inertia — Newton's first law

9.5.1 Forces and motion

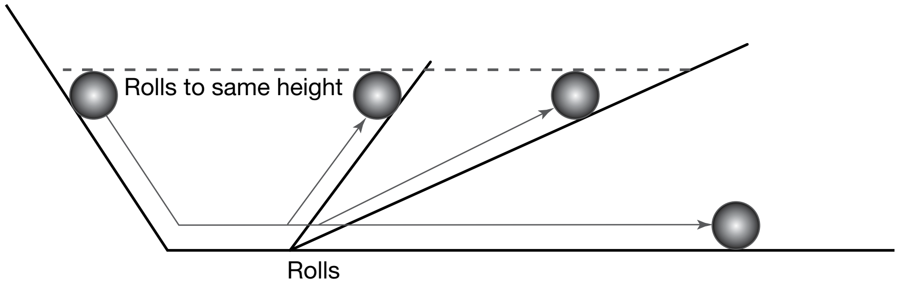
The motion of a vehicle can be described using concepts like speed and acceleration, but explaining why a vehicle travels at a constant speed or in fact accelerates requires an examination of the forces acting on that vehicle. Explaining motion in terms of the forces acting originated in the early 1600s through the work of the Italian physicist, Galileo Galilei. Prior to that it was believed that objects moved because of a property early scientists called *impetus*. Their theory was that when you applied a force to the object, you transferred impetus to it, which caused it to move. However, as the object moved, it used up the impetus and when the impetus ran out, it stopped.

Galileo's ideas on motion

Galileo was not convinced about the impetus model of motion, and set about examining the nature of forces and motion through a long series of experiments.

One of his famous experiments was to roll a cannonball down a smooth ramp and then up a second ramp. He noticed that the cannonball rolled back up to the same height from which it had been released. When he lowered one side of the ramp a little, he found that the ball rolled on further until it once again reached the original height. He then imagined that if the far side was kept flat so that it never rose up to the original height, then the ball would roll on and on forever, trying to reach its starting height.

Galileo's cannonball experiment



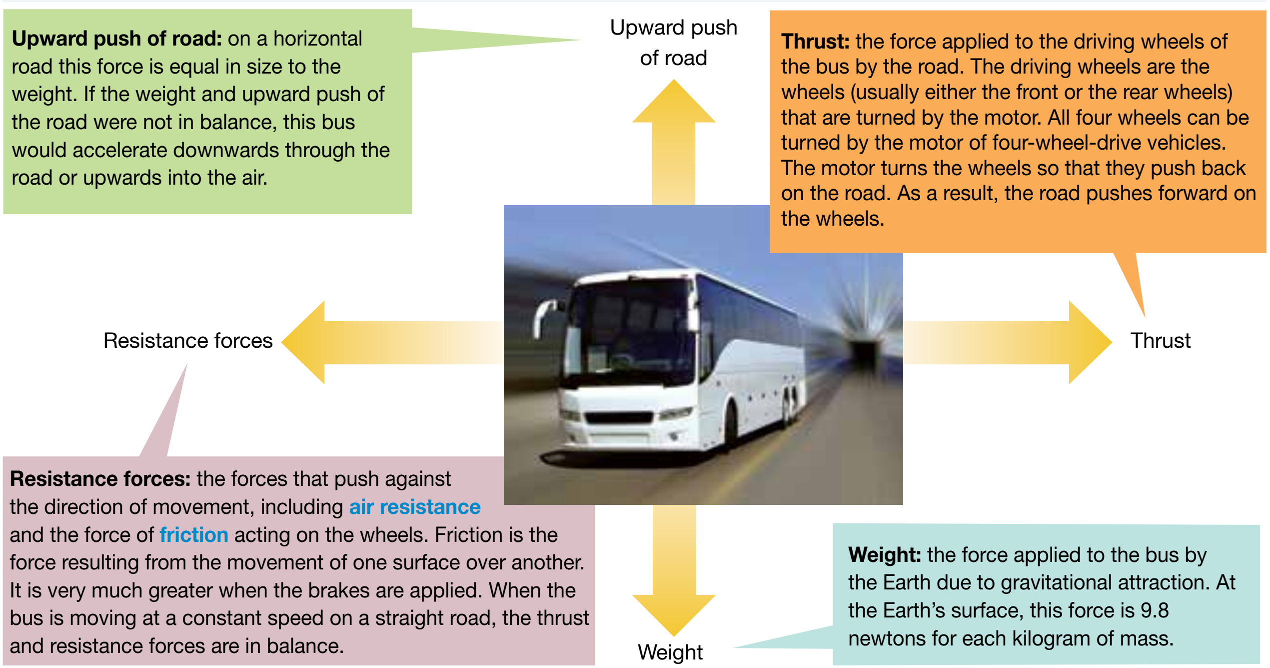
Newton's laws of motion

The idea that objects would continue to move in a straight line unless acted upon by a force originated with Galileo, but Sir Isaac Newton linked this idea to a bigger picture of motion that is described by three laws. These are known as **Newton's laws of motion**.

Like Galileo, Newton realised that any change to the motion of an object was caused by the combined effect of the forces that acted on that object. When the forces acting on the object balanced out, there would be no change to the object's motion. If the forces acting on the object were not balanced, then the motion of the object would change — it may accelerate, decelerate or change direction.

Let's examine the typical forces acting on a moving bus as shown in the picture below. When the thrust acting on the bus is greater than the resistance forces acting on it, the bus accelerates and, when the resistance forces are greater than the thrust, the bus decelerates. If the thrust and the resistance forces are equal in size the bus maintains its state of motion — either remaining at rest or continuing to move at its current speed.

The forces acting on a moving bus. The forces are in balance when the bus is not changing speed or direction.



INVESTIGATION 9.5

Forces on cars

AIM: To account for the motion of a toy car in terms of the forces acting

You will need:

toy car

- Rest a toy car on a smooth, level surface.
- Push the car quickly forwards and then let it go.

Discussion

1. What forces are acting on the car while it is at rest?
2. How do you know that there is more than one force acting on the car while it is at rest?
3. Are the forces on the car in balance after you stop pushing? How do you know?
4. Which force or forces cause the car to slow down after you stop pushing it forwards?
5. How would the car's motion be different if you pushed it forwards and let it go on:
   (a) a much smoother surface
   (b) a rough surface?

9.5.2 Inertia

Think back to a bus ride you have taken where you were a standing passenger. Can you recall an instance in which the bus stopped suddenly and you were thrown forwards, or perhaps as the bus turned a corner you had to quickly grab a hand rail because your body was pulled sideways?

What you experienced is explained by Newton's First Law of Motion, often called the law of inertia. Newton's First Law of Motion can be stated as:

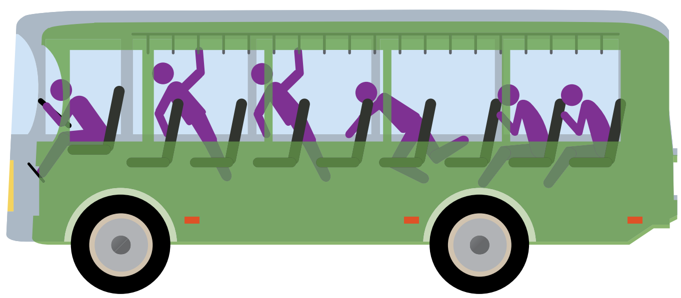
An object will remain at rest, or will not change its speed or direction, unless it is acted upon by an unbalanced force.

In each of the cases just mentioned, an unbalanced force is acting on the bus to change its speed or direction. For example, when the bus driver applied the brakes, the braking force exceeded the thrust force from the driving wheels and so the bus quickly slowed. However, this unbalanced force did not act directly on you, the passenger and so even after braking you continue moving forward at the same speed and direction until you apply a force to stop your motion; for example, by grabbing onto a hand rail.

This tendency of an object to resist changes to its motion is called inertia. Generally, the heavier the object is, the greater its inertia and the harder it is to change its current motion. For example, it takes a much larger braking force to slow the motion of a freight train than it does to slow the motion of a bicycle.

Have you ever seen a magician whip away a tablecloth from a table, leaving the plates and

Passengers are thrown forwards when a bus stops suddenly because of their inertia.



Don't try this at home!

cutlery on it completely undisturbed? Well that's due to inertia as well! There is a small amount of frictional force acting between the crockery and the tablecloth. If the tablecloth is pulled very quickly, the frictional force does not act for long enough to make the crockery move along with the tablecloth, and the inertia of the crockery keeps it in place on the table. The tablecloth, being very light, has very little inertia and is easily moved quickly by the magician.

INVESTIGATION 9.6

Looking at inertia

AIM: To investigate the property of inertia in two small masses

You will need:

5 cent and 20 cent coins
sheet of A4 paper

- Place a sheet of A4 paper at the end of a smooth table so that one end of the paper overhangs the end of the table by a few centimetres. Place a 20 cent (or heavier) coin in the centre of the sheet of paper.
- Pull the paper from underneath the coin very quickly. (You may need to do this a few times so that you can be sure you are pulling it fast enough.) Observe what happens to the coin. Now pull out the paper more slowly and, again, observe what happens to the coin.
- Repeat the experiment steps detailed above, only this time use a 5 cent coin.

Discussion

1. What happens to the coin when the paper is pulled out quickly?
2. Are the forces acting on the paper balanced? Explain your answer.
3. Explain why the coin behaves in the way it does.
4. How is the behaviour of the coin different if the paper is pulled out more slowly? Suggest a reason for the change in behaviour.
5. Is it easier or more difficult to pull the paper out from beneath the lighter coin? Suggest a reason for your answer.

INVESTIGATION 9.7

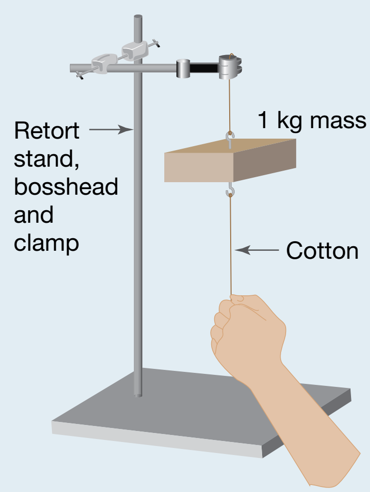
Snap!

AIM: To investigate the effect of inertia on the breaking force in a string

You will need:

retort stand with bosshead and clamp
3 cotton threads (each approx. 30 cm long)
1 kg mass, with a hook on the top and bottom
50 g mass

- Arrange the equipment as illustrated at right.
- Predict which length of cotton will snap. Will it be the upper or the lower?
- Taking extreme care to protect your fingers, hold the bottom length of cotton and gently pull.
- Replace the broken length of cotton.
- Repeat the experiment, but this time pull very rapidly on the lower length of cotton. The quicker you pull the better.
- Record your observations in your notebook.
- Repeat the experiment using a 50 g mass.



Discussion

1. How does the inertia of the 1 kg mass affect your results?
2. Why does the size of the acceleration that you are trying to give to the mass affect your results?
3. Predict your results if you use a 50 g mass instead of a 1 kg mass.
4. How do your results for the 50 g mass compare with:
   (a) your prediction
   (b) the results for the 1 kg mass?

9.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** two forces that resist the forward motion of a bus.
2. **State** Newton's First Law of Motion.
3. Give two different examples of Newtons First Law of Motion.

Think

4. **Describe** the main differences between Galileo's ideas of motion and the impetus theory.
5. **Identify** which is greater — the thrust or the resistance forces — when a bus is moving along a horizontal road with:
   (a) increasing speed
   (b) decreasing speed
   (c) constant speed.
6. **Explain** in terms of Newton's first law why you should never step off of a bus or train before it has completely stopped.
7. When a car accelerates away from a green light, passengers are forced back into the seat. Using Newton's first law, **explain** why this happens.
8. Can you remember some rough bus trips you have had? What would be your immediate resulting motion as a passenger on the bus without a seatbelt if the bus performed the following manoeuvres:
   (a) a very quick start from rest?
   (b) a forward motion at constant speed?
   (c) a very sharp right-hand turn?
   (d) an emergency stop from a speed of 60 km/h?
9. Use the **Roller-coaster** weblink in the Resources tab and your knowledge about forces and motion to build a roller-coaster that is both safe and fun.

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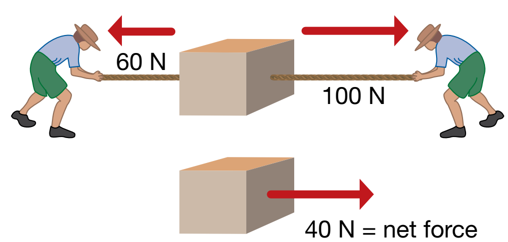
Explore more with this weblink: Roller-coaster

9.6 Acceleration and Newton's second law

9.6.1 Net force

As we have seen, the speed or direction of an object changes when the forces acting on it are unbalanced. When forces acting on an object are unbalanced, a net force results in an object accelerating.

For example, in the diagram at right two boys are pulling on a box. For the moment, we'll ignore friction, weight and the upward push of the ground and just look at the forces with which the boys are pulling on the ropes. If one boy pulls the box to the right with a force of 100 N, while the other pulls to the left with 60 N, we can say that the net force acting on the box is 40 N to the right. The box will start to move to the right — in other words, it will accelerate from rest because of the unbalanced forces.



But how fast the box accelerates depends upon the mass of the box. Obviously, given a constant force, a bigger mass will mean a smaller acceleration because it has more inertia.

In the World's Strongest Man Super Series, one of the events requires the competitors to move a very heavy object. For example, they could be asked to tow a truck, a train or even an aircraft from a standing start. If the competitors are to accelerate the truck from rest, they will need to exert a large force. The greater the force that the strongman applies to the truck, the more the truck will accelerate.

This is the essence of **Newton's Second Law of Motion**:

The size of an object's acceleration depends directly on the size of the net force acting on it and is inversely proportional to its mass.

This is represented by the formula:

$$\text{acceleration} = \frac{\text{net force}}{\text{mass}}$$

An event in the World's Strongest Man Super Series

or, more commonly,

$$\text{net force} = \text{mass} \times \text{acceleration}$$

and abbreviated to

$$F = ma.$$

When using Newton's second law, the units for force are newtons (N), mass is in kilograms and acceleration is in m/s^2.

9.6.2 Newton's second law in action

The launching of a space shuttle at Cape Canaveral in Florida was a spectacular sight. At launch, the space shuttle would have a mass of about 2.2 million kilograms. (About 86 per cent of this mass was fuel, most of which was burnt during the launch.) Two forces act during blast off:

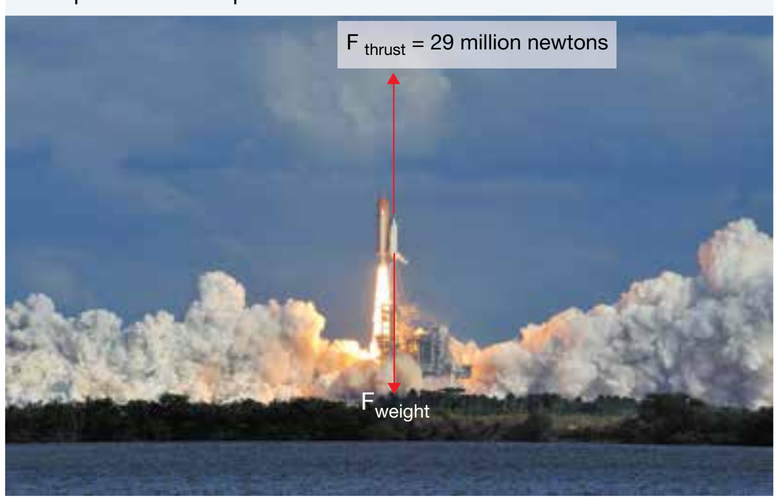
- the downward pull of gravity (weight). The weight of the space shuttle at blast-off was about 22 million newtons.
- the upward thrust resulting from the burning of fuel, which is about 29 million newtons.

The forces acting on the space shuttle at launch were not balanced. The net force on the space shuttle was 7 million newtons upwards. Newton's second law can be used to estimate the acceleration of the space shuttle at blast-off:

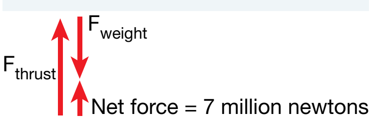
$$\begin{aligned} a &= \frac{F}{m} \\ &= \frac{7\,000\,000 \text{ N upwards}}{2\,200\,000 \text{ kg}} \\ &= 3.2 \text{ m/s}^2. \end{aligned}$$

In other words, the space shuttle gained speed at the rate of only 3.2 m/s (or 11.5 km/h) each second. No wonder blast-off seemed, to take forever!

The space shuttle was launched by powerful rockets — yet it seemed to take forever to get off the ground. Newton's second law provides an explanation.



Calculating the net force on a space shuttle



Newton's second law also explains why the small acceleration at blast-off was not a problem. As the fuel was rapidly burnt, the mass of the space shuttle became smaller. As this happened, the acceleration gradually increased, and the space shuttle gained speed more quickly. Remember that for a given net force, the less the mass, the greater the acceleration.

INVESTIGATION 9.8

Force, mass and acceleration

AIM: To investigate how the mass of an object affects its acceleration

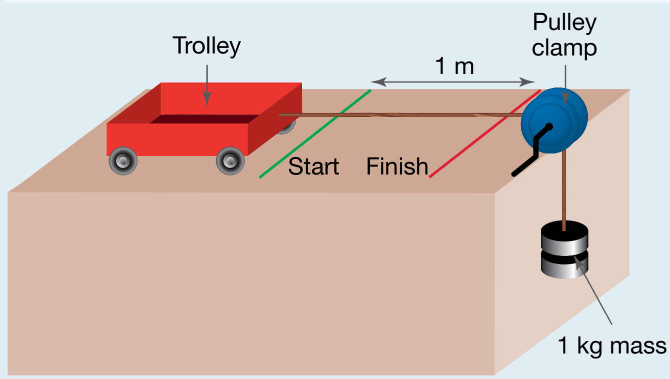
You will need:

a dynamics trolley
four 500 g masses
a stopwatch
metre ruler
string
a 1 kg mass
masking tape
pulley clamp

- Draw a data table in your notebook similar to the one shown below.
- On your bench top, use the masking tape and the metre ruler to mark out the starting line and finishing line for a 1 m long course for your dynamics trolley.
- Set up the equipment as shown below right. Place the trolley at the starting line.
- Start the stopwatch at the same moment the 1 kg mass is dropped, and time how long the unladen trolley takes to cross the finish line. Enter the time in the data table. Repeat this step twice more and then determine the average race time.
- Place a 500 g mass on the trolley and repeat the previous step.
- Repeat the experiment with increasing masses of 1000 g, 1500 g and 2000 g.

Mass on the trolley (g)	Time (s)			
	Trial 1	Trial 2	Trial 3	Average
0				
500				
1000				
1500				
2000				

String tied to a dynamics trolley and connected to a suspended weight via a pulley clamp



Discussion

1. Which of the trolleys had the fastest race time? How can you tell if it had the fastest acceleration?
2. The equation $d = \frac{1}{2}at^2$ allows you to calculate the size of the acceleration that was acting on the trolley each time, where d = distance, and t is the average race time to cover the distance. As d = 1 m, this equation simplifies so that we get: $a = \frac{2}{t^2}$.
   Use this equation and the average race times in the table to determine the average acceleration of the trolley for each mass load.
3. The weight of the 1 kg mass provided the force to move the trolley. Calculate the size of this force.
4. Was the weight of the 1 kg mass the only force acting on the trolley? What other forces can you identify that would have affected the trolley's acceleration?
5. Were the forces acting on the trolley each time balanced or unbalanced? How can you tell?
6. Give a general statement about the relationship between the mass of the trolley and its acceleration from a constant force.

9.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Express Newton's second law in symbols. **Explain** what each symbol represents and state the units that each is measured in.
2. **Explain** in terms of Newton's second law why the acceleration of the space shuttle gradually increases as it rises.

Think

3. Two identical toy carts A and B, each having a mass of 1.0 kg, are pushed across a smooth, level table top with the same force. One of the carts contains a heavy brick. Cart A accelerates more rapidly than cart B.
   (a) **Identify** which cart contains the brick. **Explain** how you know this.
   (b) If the acceleration of cart A is 2.0 m/s^2, **calculate** the total force acting on each cart.
   (c) If the acceleration of cart B is 0.5 m/s^2, what is the mass of the brick?
4. **Calculate** the total force that would cause a 1.5 kg salad bowl to accelerate across a table at 0.30 m/s^2.
5. A 10 kg sled is pulled across the snow with a force of 40 N giving it an acceleration of 3.0 m/s^2. **Calculate** the friction force on the sled.
6. Rearrange the equation $F = ma$ so that the subject of the equation is now m.

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Complete this digital doc: Worksheet 9.3: Newton's Second Law (doc-12793)

9.7 Forces in pairs — Newton's third law

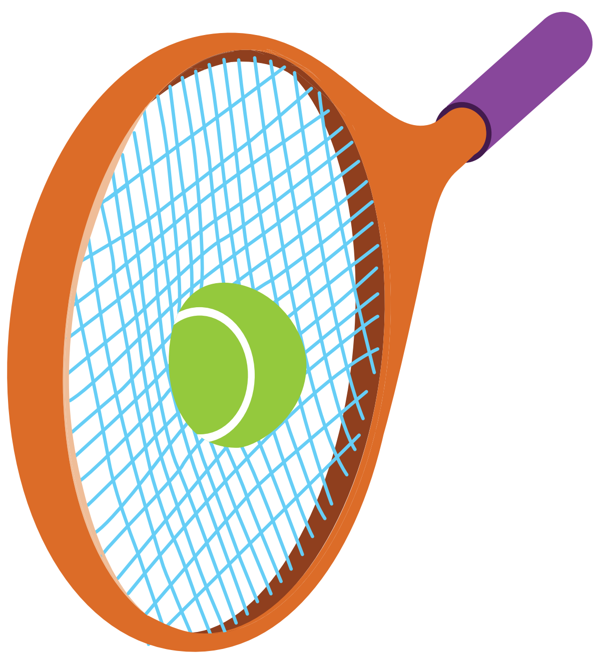
9.7.1 Equal but opposite

When you've blow up a balloon and then let it go, you would have noticed that the escaping air goes in one direction while the balloon itself goes the other. This is an example of Newton's Third Law of Motion which is often expressed as 'for every action there is an equal and opposite reaction'. But what does this mean? Newton's third law explains how forces occur in pairs and these forces are equal in magnitude and opposite in direction.

With this in mind, Newton's third law can be stated more explicitly as follows:

If object A applies a force on object B, object B will apply an equal force back on object A.

Hitting a tennis ball demonstrates Newton's third law. Action–reaction forces cause both the racquet and ball to be compressed.



These forces are exerted while the two objects are in contact. For example, when the head of a tennis racquet strikes a ball, the racquet exerts a force on the ball and, at the same time, the ball exerts a force of the same size back on the racquet. You can feel the strain on your muscles due to the reaction force as you strike the ball.

Whether you are getting around on the ground, in the air or even in outer space, force pairs are acting to move objects around.

- When an athlete pushes back on a starting block, the starting block pushes the athlete forwards.
- The forward push on the driving wheels of a car from the road occurs only because the wheels push back on the road as they are forced to turn and grip the road.
- When you swim through the water, you push back on the water with your arms and legs causing the water to push you forward.

9.7.2 Up and away

The force that pushes a jet aeroplane forward is provided by the exhaust gases that stream from its engines. As the jet engines push the exhaust gases backwards, the gases push forwards on the plane with an equal and opposite force. This forward push is called the **thrust**. In order to equal or exceed the resistance to the jet's motion, the thrust needs to be very large. The photograph at right shows the huge blades inside a jet engine. The blades compress the air flowing into the engine and push it into the combustion chamber behind the blades. In the combustion chamber, fuel is added and burns rapidly with the compressed air. The exhaust gases are forced out of the engine at very high speed.

The huge blades of a jet engine suck in and compress air so that the fuel inside burns rapidly. Exhaust gases are then forced out at high speed.

HOW ABOUT THAT!

Rockets, believed to have been invented by the Chinese, have been used as weapons since the thirteenth century.

9.7.3 Blast off

The rockets used to launch spacecraft also provide a thrust force resulting from an action–reaction force pair. Like jet engines, they push exhaust gases rapidly out behind them. As the rocket pushes the gases out, the gases push back, providing a thrust force on the rocket.

Unlike jet engines, rockets used to launch spacecraft do not use air to burn fuel. They carry their own supply of oxygen so that the fuel can burn quickly enough to lift huge loads into space. The oxygen is usually carried as a liquid or a solid. Once spacecraft are in orbit, smaller rockets can be used to make the craft speed up, slow down or change direction.

INVESTIGATION 9.9

A balloon rocket

AIM: To design a balloon rocket that will travel the maximum distance

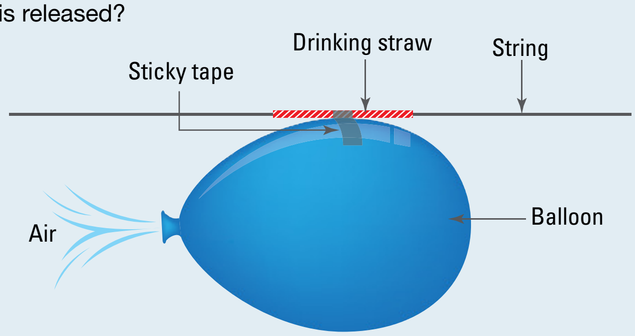
You will need:

balloon
a length of string that will span the classroom
drinking straw
scissors
sticky tape
tape measure

- Tie the end of the string to a structure at the far end of the classroom. This will serve as a guide rope.
- In groups, design a balloon rocket that when inflated will travel the greatest possible distance along the guide rope.
- Inflate a balloon and hold the opening closed.
- Sticky tape a section of the drinking straw to the inflated balloon — this will be fed through the start of the guide rope.
- Take turns releasing the balloon and observe its motion through the room.
- Use the tape measure to record the distance travelled by each group's balloon rocket and record the results on the board.

Discussion

1. Explain what happens to the air inside the balloon when you release the balloon.
2. Which way does the balloon move as the balloon is released?
3. What provides the force that pushes the balloon through the air?
4. Explain why it is essential to tape the section of drinking straw to the balloon and to feed it through the string.
5. Suggest how your balloon rocket could be improved.
6. Compare the way that the balloon is propelled and the way that a jet engine works. How is it similar? How is it different?



INVESTIGATION 9.10

Stop pushing!

AIM: To investigate the acceleration of two objects involved in an action–reaction pair

You will need:

2 people of about the same mass
2 chairs with wheels
strong rope (approx. 2–3 m long)
long broom handle

- Give each of the seated people one end of the rope.
- This experiment will only work if the pushes and pulls are performed gently and smoothly.
- Have the two people each take it in turns to pull gently on the rope.
- Record your observations.
- Repeat the experiment, but now have both people pull gently at the same time.
- Repeat the experiment, but this time push gently on the broom handle instead of pulling on the rope.
- Record any differences to the previous situation.
- Replace one of the people with someone who is significantly different in weight.
- Repeat the steps.

Discussion

1. Did changing who was pulling have any effect on what happened?
2. How do the masses of the people affect their respective accelerations?
3. How do the forces on each person compare? (*Hint*: Think of Newton's third law.)
4. Use Newton's second law to explain why the same force can produce different accelerations.
5. Draw a diagram showing the action and reaction forces that acted on the two people. Don't forget to include the action/reaction forces involving the force of gravity and the chair.

9.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** Newton's Third Law of Motion.
2. Give three examples of force pairs. Be sure to state what each force is acting on.

Think

3. When you walk forwards, **identify** what force provides the forward push.
4. **Describe** in what way rockets are similar to jet engines. In what way are they different?
5. When Dina turned on the water to her hose without holding onto the end of it, the water rushed out of the hose nozzle and the hose itself started to snake around the yard. **Explain** why the hose moved around like this.
6. Every time Dylan takes his dog Frisbee for a walk, the dog always pulls hard on the leash. This nearly pulls Dylan's arm out of its socket and Frisbee almost chokes himself! **Explain** these effects in terms of Newton's third law.
7. How do cricketers reduce the impact of the force on their hand when they catch a fast moving cricket ball?

Investigate

8. **Investigate** how a hovercraft works. What force pairs are involved in its operation?
9. Test your ability to identify Newton's Laws in action by completing the **Time Out 'Newton's Laws'** interactivity in the Resources tab.

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Try out this interactivity: Time Out 'Newton's Laws' (int-0055)

Complete this digital doc: Worksheet 9.4: Newton's Third Law (doc-12794)

9.8 Making cars safer

9.8.1 Inertia and car design

In 1970, there were about 6 million vehicles being driven on Australia's roads. During that year 3798 people lost their lives in road accidents. Now there are about 14 million vehicles on Australia's roads. Yet the number of lives lost each year in road accidents now averages about 1400.

One of the key reasons for the reduction in the road toll is that the cars we drive today are safer than ever before. Cars are designed by engineers who use scientific principles and experimental testing to make cars more efficient and, most importantly, safer.

Safety features such as seatbelts, collapsible steering wheels, padded dashboards, head restraints, airbags and crumple zones have to be tested by engineers before being introduced. The testing continues after introduction as car manufacturers strive to make each new model even safer.

Testing of safety features involves deliberately crashing cars with 'crash test dummies' as occupants. The dummies are constructed to resemble the human body and numerous sensors are used to detect and measure the effects of a collision.

Crash test dummies are used to model the effects of collisions on the human body.

Before real crash testing takes place, engineers use computer modelling to simulate crashes with 'virtual' cars.

Most deaths and serious injuries in road accidents are caused when the occupants collide with the interior of the vehicle or are 'thrown' from the vehicle. In a head-on collision the vehicle stops suddenly. However, unrestrained occupants continue to move at the pre-collision velocity of the vehicle until they collide with the steering wheel, dashboard or windscreen. Seatbelts provide a restraining force on the occupants so that they don't continue moving forwards, potentially injuring themselves. Front airbags reduce injuries caused by collisions between the upper body (which is still moving) and the steering wheel, dashboard or windscreen.

Side airbags are standard safety features in most cars today. They protect occupants in the event of a side-on collision. The more recent airbag technology measures the size of the impact and delays inflation until just the right moment. These improvements are the direct result of computer modelling and crash testing.

Computer modelling allows engineers to study the forces acting on virtual crash test dummies to assess trauma in crash test situations. Modelling allows engineers to study the effects of slight changes to a multitude of variables such as seatbelt position, airbag size etc. in an effort to design the best possible safety features.

Head restraints on seats reduce neck and spinal injuries, especially in a vehicle that is struck from behind by another vehicle. An impact from the rear pushes a vehicle forwards suddenly. Your body is pushed forwards by your seat. However, without a head restraint, your head remains where it was. The sudden strain on your neck can cause serious spinal injuries. Neck injuries caused this way are often referred to as whiplash injuries. Some new cars have head restraints that automatically move forward and up when a collision occurs.

9.8.2 The zone defence

The occupants of a car sit in a very strong and rigid 'protection zone' designed to prevent outside objects (including the car's engine, other cars and tree trunks) from entering the passenger compartment and causing injuries during a collision. The roof panel is supported by strong columns to make it less likely to be crushed.

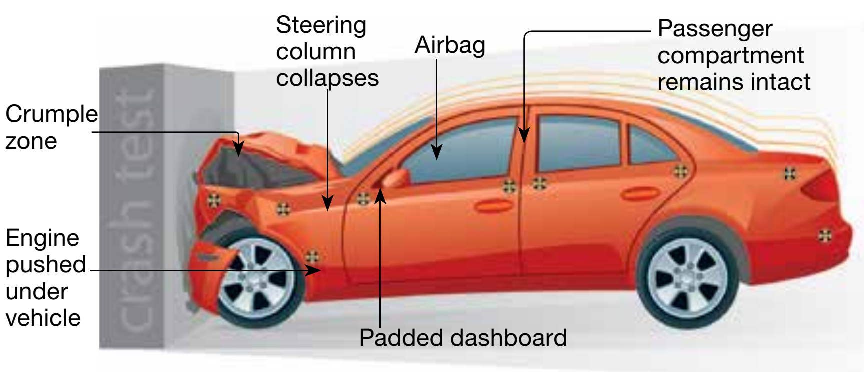
The rigid passenger compartment is flanked by crumple zones at the front and rear of the vehicle. These zones are deliberately designed to crumple, absorbing and spreading much of the energy transferred to the vehicle during a collision. As a result, less energy is transferred to the compartment carrying the occupants, reducing the chance of injuries. The crumple zone also allows the vehicle to stop more gradually. Without a crumple zone, the vehicle would stop more suddenly and perhaps even rebound. As a result, occupants would make contact with the interior at a greater speed and there would be a greater chance of serious injury or death.

A stationary car is struck from behind by another vehicle. Without a head restraint, your head remains at rest and is pulled forwards by your neck as the car jerks forward, causing injury.

The passenger compartment being tested. The front crumple zone absorbs and spreads energy. It also allows the car to stop more gradually.

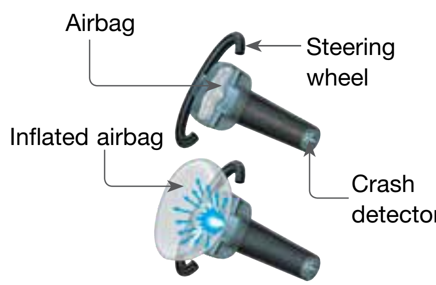
The rigid roof panel and strong pillars that support it are part of the 'protection zone'.

Car safety features employed in a frontal collision



9.8.3 How an airbag works

- The airbag is made of a thin, nylon fabric, which is folded into the steering wheel, dashboard or doors.
- When a crash is sensed, the control unit sends an electrical signal to the inflator. A chemical reaction is initiated by the igniter, generating primarily nitrogen gas to fill the airbag, causing it to deploy.
- Airbags must inflate rapidly to decrease the risk of occupant injuries. From the beginning of the crash, the entire deployment process is about 50 milliseconds.



9.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** six safety features that are designed to make cars safer in the event of a collision.
2. **Outline** how engineers test vehicle safety features to make sure that they do what they are designed to do.
3. **Describe** what happens to the motion of an unrestrained occupant when a car suddenly stops because it has collided head-on with another car or object.
4. **Explain** how each of the following features protects occupants during a collision.
   (a) Seatbelts
   (b) Airbags
   (c) Head restraints
5. **Recall** what crumple zones are and **describe** how they protect the occupants of a vehicle during a collision.
6. **Explain** why it is important that there is a strong and rigid zone between the two crumple zones of a car.

Think

7. The safety features described in this section are designed to reduce the chances of serious injury or death when a collision takes place. Scientists and engineers have designed many other safety features in cars and other vehicles that reduce the chances of a collision actually taking place. Work in a group to brainstorm these features and complete a table like the one that follows.
   Some examples are included to help you get started.

Safety features designed to prevent collisions

Feature	How the feature works
Tyre tread	Increases friction and makes steering and braking more reliable, especially in wet weather. The tread even pushes water out from beneath the tyre when the road is wet.
Windscreen wipers	Keeps the windscreen clear to ensure good visibility for the driver.
Speed alarm	The driver selects a maximum speed. If that speed is exceeded an alarm sounds, warning the driver to slow down.

Investigate

8. Use secondary sources to **investigate** the following:
   (a) How anti-lock brake systems (ABS) make braking in an emergency situation safer
   (b) The benefits of electronic stability control (ESC).
9. Design a car with state-of-the-art safety features. Create a poster or multimedia presentation to present your car design and to showcase the safety features, explaining how they improve passenger safety with reference to Newton's laws of motion. The purpose of your poster/presentation is to convince safety minded consumers to purchase your car, so referring to scientific principles will add credibility to your sales pitch.

9.9 Project: Rock'n'roller-coaster

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9.9.1 Scenario

Many psychologists think that the reason roller-coasters are so popular is tied up with the 'rush' that follows stimulation of the fear response. When exposed to the combination of speed, noise, high hills, twists, loops and steep descents of the ride, our brains tell us that there is some element of threat or danger. This triggers our 'fight or flight' instinct, sending adrenaline coursing through our bodies in a way which many people find very stimulating. Of course, some of us just throw up rather than finding it fun!

Thrill-ride engineers say that the aim of a good ride is to provide a simulation of danger without actually putting people at risk. By manipulating the characteristics of gravity, periodic motion and speed, these engineers use physics to trick the body into thinking that it is in a lot more trouble than it really is. But the line between a ride that thrills and a ride that kills is a very narrow one, and the structural and mechanical engineers who design and build these rides must test their designs rigorously by using computer models or even physical models before the first steel rail leaves the factory! So how would you, as a team of roller-coaster engineers working at the new theme park Chunderworld, design a roller-coaster that was high on the thrill but zilch on the kill?

9.9.2 Your task

- You will use your knowledge of physics and forces to design and build a model roller-coaster that has a set length and includes a minimum number of loops, hills and turns. Your design will also include a roller-coaster car that will travel along the length of the track. In order for the design to be considered successfully tested, your car must be able to travel the length of the track and then be brought to rest within the last 50 cm without derailing.
- You will draw a plan or diagram of your roller-coaster identifying the positions and types of components used — hill, turn, twist or loop — and the points at which the car has the highest and lowest values of kinetic energy and gravitational potential energy.
- Finally, you will set up a blog which includes:
  (a) a summary of how the kinetic energy and gravitational potential energy values change over the course length
  (b) a log describing the development, building and testing of your roller-coaster and its different sections, including the method used to bring the car to a safe stop at the end
  (c) your drawing/plan of your completed roller-coaster
  (d) video footage of your roller-coaster in action from start to finish.

9.9.3 Process

- Start your research. Make notes of information you discover that will assist you in your design. Enter your findings as articles under your topic headings in the Research Forum. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about different aspects of roller-coaster design.

- Set up your blog and start with a summary of what you have found out about how energy is transferred and transformed during a roller-coaster ride. Make regular entries in your blog over the course of the project, describing the process of designing, building and testing your roller-coaster from start to finish. Everyone in the group should contribute to the diary/log.
- Design, build and test your roller-coaster. Each member of the group should be responsible for a section of the ride. Don't forget to update your blog as you go.
- Use a camcorder, digital camera with video mode or other video device to film your roller-coaster in action. Edit and save your video file.
- Add your finished plan and your video to your blog.

9.10 Review

9.10.1 Describing motion

- **distinguish** between distance and displacement 9.2
- **contrast** the instantaneous and average speed of moving objects 9.3
- **calculate** and compare the speed and velocity of moving objects 9.3
- **describe** how velocity can be determined from a displacement–time graph 9.3
- **investigate** the speed of an object using a ticker timer 9.3
- **relate** acceleration to a change in speed or direction 9.4
- **calculate** the acceleration of an object 9.4

9.10.2 Forces and motion

- **describe** the contribution of Galileo to our understanding of forces 9.5
- **recall** the unit of force 9.5
- **identify** the forces that act on a vehicle in motion 9.5
- **distinguish** between balanced and unbalanced forces 9.6
- **describe** what is meant by the term 'net force' and calculate the net force in familiar situations 9.6

9.10.3 Newton's laws of motion

- **state** Newton's three laws of motion 9.5, 9.6, 9.7
- **define** the term 'inertia' 9.5
- **relate** the concept of inertia to everyday situations 9.5
- **state** the equation that relates the net force to mass and acceleration 9.6
- **identify** some common action–reaction pairs 9.7

9.10.4 Advances in car safety

- **explain** how inertia acts on the passenger of a car which suddenly changes its motion 9.8
- **explain** how modern car safety features such as seatbelts, airbags and head restraints improve passenger safety 9.8

Individual pathways

ACTIVITY 9.1	ACTIVITY 9.2	ACTIVITY 9.3
Revising movement doc-10663	Investigating movement doc-10664	Investigating movement further doc-10665

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FOCUS ACTIVITY

Carry out a first-hand investigation to examine the relationship between the accelerating force on a vehicle and its acceleration. A trolley can be accelerated by suspending a 50 g mass carrier over the edge of a bench and attaching it to the trolley via a pulley clamp. Leave the other nine 50 g masses in the trolley initially. Use a ticker timer to obtain velocity–time data, plot this graph and find the gradient to determine the trolley's acceleration. Vary the mass suspended and hence the accelerating force by transferring 50 g masses from the trolley to generate sufficient acceleration values to allow a further plot of accelerating force versus acceleration. Alternatively a data logger may be used to determine acceleration directly for each run.

Access more details about focus activities for this topic in the Resources tab (doc-10662).

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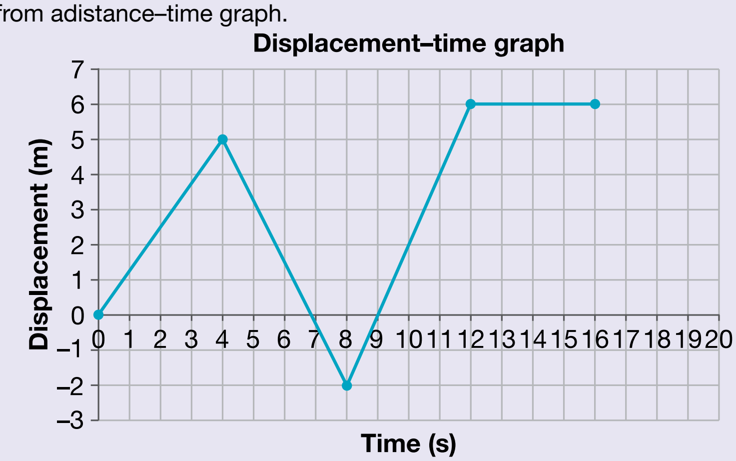
9.10 Review 1: Looking back

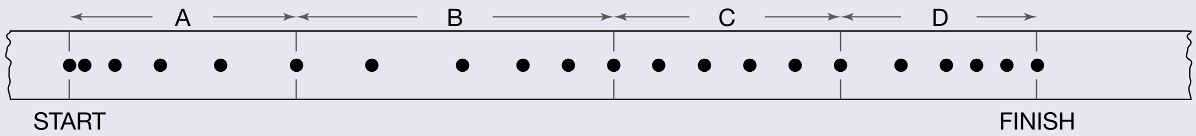
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. A scientist investigating the flight patterns of a fly observed the following:
   The fly flew 4 m forward then 5 m back and then, finally, 3 m forward, where it lay on its back buzzing.
   (a) **Construct** a distance–line graph to represent this flight.
   (b) **Calculate** the distance travelled by the fly.
   (c) **Calculate** the fly's final displacement from its starting position.
2. **Describe** how you can calculate speed from adistance–time graph.
3. A traveller at a bus stop was observed walking about while waiting for the bus. Use the graph at right of the traveller's movements to answer the questions below.



   (a) **Identify** the traveller's displacement after 4 seconds.
   (b) After 8 seconds the traveller has a displacement of –2 m. **Explain** what the negative sign indicates.
   (c) After 16 seconds:
      (i) **Identify** how far the traveller is from the starting position.
      (ii) Is the traveller in front of or behind the starting position? **Explain** your answer.
      (iii) **Calculate** the total distance the traveller has moved since leaving the starting position.
   (d) **Identify** the time intervals over which the traveller did not change position.
   (e) **Calculate** the gradient between the start and the 4 seconds mark.
   (f) **Calculate** the velocity between the start and the 4 seconds mark.
   (g) **Calculate** the velocity between 8 and 12 seconds.

4. Use the appropriate rule to **calculate** the average speed (in m/s) in each of the following:
   (a) A 1200 m drive to the shops in 60 seconds
   (b) A 45-second walk over a 9 m distance.
5. **Calculate** how far a baby crawls in 20 seconds if its speed is 0.5 m/s.
6. The diagram below shows part of the ticker tape record of the motion of a toy car as it is pushed along a table. As the tape moves through the ticker timer, a new black dot is produced every fiftieth of a second (0.02 s). The ticker tape has been divided into four equal time intervals labelled A, B, C and D.

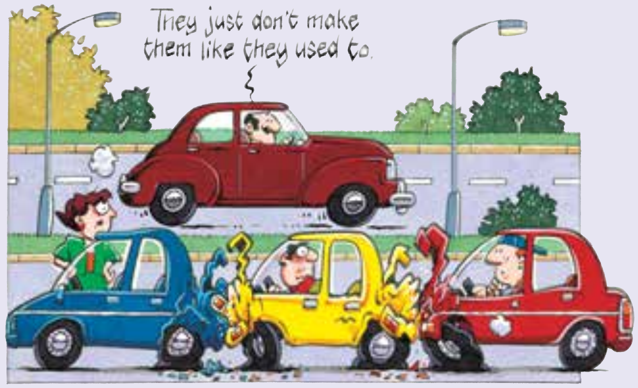


   (a) **Identify** the time intervals during which the speed of the toy car is:
      (i) increasing
      (ii) decreasing.
   (b) **Identify** the time intervals during which the:
      (i) speed of the toy car is constant
      (ii) acceleration of the toy car is constant.
   (c) **Identify** in which of the four intervals the total force acting on the toy car was zero.
   (d) **Identify** in which of the four intervals the unbalanced force was acting on the toy car in the same direction as that in which the car was moving
   (e) What period of time is represented by each of the four time intervals? Express your answer in decimal form.
   (f) Assuming the tape is to scale, **calculate** the average speed during the entire time interval represented by the ticker tape.
7. Use Newton's second law to **calculate** answers for the following:
   (a) A 1400 kg car accelerates at 3.0 m/s^2. What size force is needed to cause this acceleration?
   (b) A force of 160 N causes an object to accelerate at 2.0 m/s^2. What is the object's mass?
   (c) A force of 210 N acts on a mass of 70 kg. What is the acceleration?
8. Seatbelts are made from a woven material. This type of material can stretch. When a seatbelt is used in a crash, this stretching can lessen the injuries experienced by the passenger. **Explain** how this occurs. Use the ideas about car crumple zones as a guide.
9. The table below provides information about four laps completed by one of the drivers in an Australian Formula One Grand Prix. The distance covered during one complete circuit of the course is 5.3 km.
   (a) Make a copy of the table and **calculate** the missing values.

Lap no.	Time (s)	Average speed (m/s)	Average speed (km/h)
5	90		
15		60	216
25	110		
35	92	57.6	

   (b) **Propose** two likely reasons for the lower average speed during lap 25.

10. Many older people who drove cars more than 50 years ago make the comment 'They don't make them like they used to' in discussions about crumple zones. They describe how older cars were stronger and tougher, and therefore safer. Write a letter to a person who has made such a statement explaining why it is better that 'they don't make them like they used to'.
11. **Explain** in terms of Newton's second law why it can be dangerous to have objects which are not tied or strapped down inside a moving vehicle.



Test yourself

1. **Identify** which of the following best describes the term inertia.
   (A) The amount of force needed to make an object start moving
   (B) The tendency of an object to resist changes to its motion
   (C) The tendency of an object to slow down regardless of the force acting on it
   (D) The force that results from Earth's gravity **(1 mark)**
2. When an air-filled balloon is released, the balloon travels in one direction while the expelled air travels in the other. This is an example of
   (A) Newton's First Law of Motion.
   (B) The law of inertia.
   (C) Newton's Second Law of Motion.
   (D) Newton's Third Law of Motion. **(1 mark)**
3. **Identify** which of the following measures instantaneous speed.
   (A) The speedometer in a car
   (B) A stopwatch
   (C) A digitector
   (D) A ticker timer **(1 mark)**
4. A car accelerates because
   (A) the resistance forces acting on the car are greater than the thrust provided by the car's engine.
   (B) the resistance forces acting on the car are smaller than the thrust provided by the car's engine.
   (C) the resistance forces acting on the car are equal to the thrust provided by the car's engine.
   (D) there are no resistance forces acting on the car when it moves. **(1 mark)**
5. Design a series of experiments that tests a variety of materials for suitability as seatbelts. You may include materials such as synthetic webbing strap, rubber, leather, lycra, woven metal, woven and knitted fabrics. In determining the best material for the job, you will need to consider:
   - how the material stretches under different loads
   - the maximum force that can be exerted on the material without breaking
   - the material's ability to return to its original length
   - how easily the material could be adjusted for user comfort.

   Write a report outlining your results and offering a suggestion as to which of the materials testedwould be most suitable for use in seatbelts. **(6 marks)**

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Complete this digital doc: Worksheet 9.5: On the move puzzles (doc-12795)

Complete this digital doc: Worksheet 9.6: On the move summary (doc-12796)

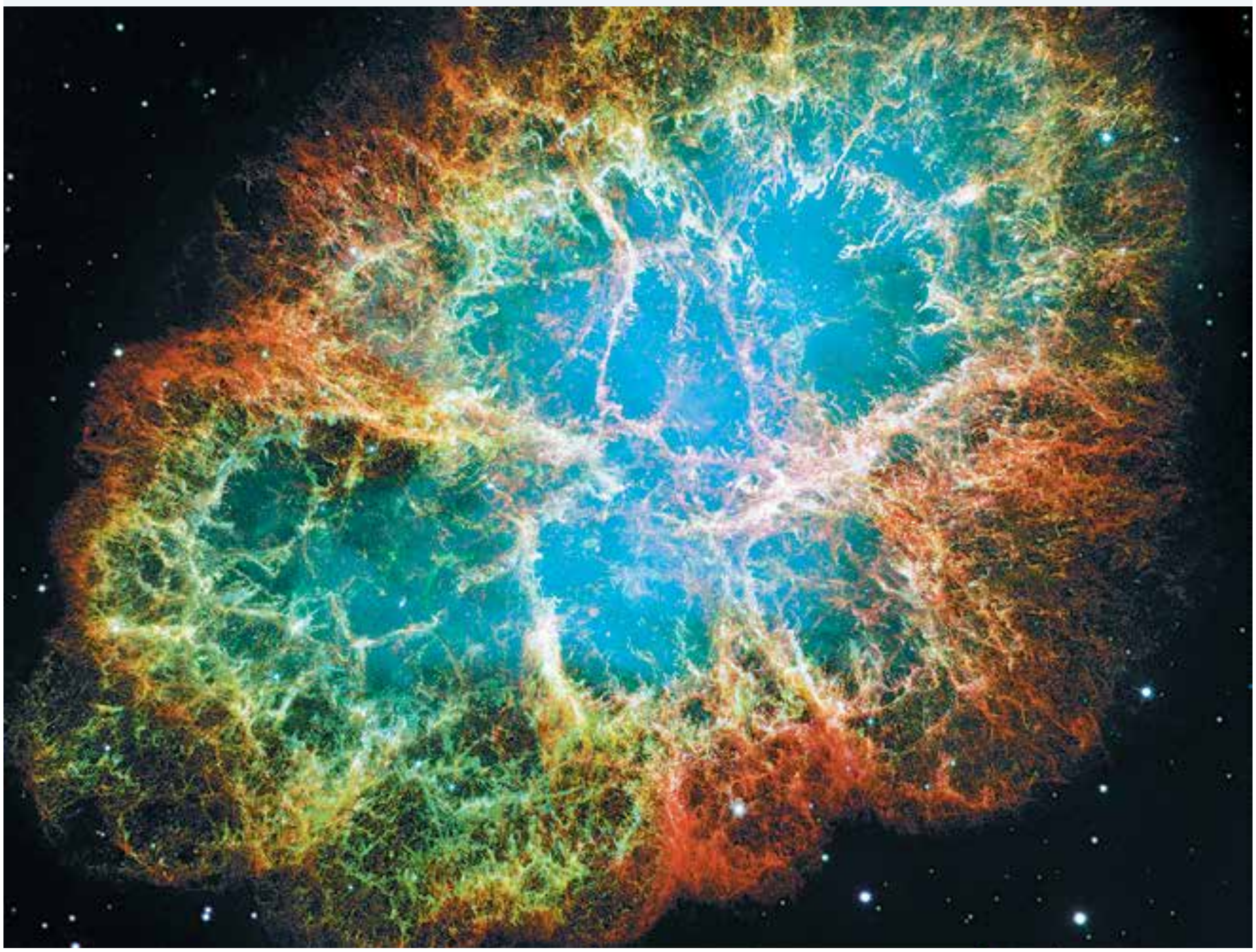
TOPIC 10
The mysterious universe

10.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

LEARNING SEQUENCE

The Crab Nebula was once a giant star. Like all stars, it had a finite life and eventually exhausted the supply of fuel sustaining a fusion reaction in its core. It exploded as a supernova in 1054.



10.1.1 Why learn this?

On any cloudless night, a pattern of stars, galaxies and clouds of gas appears to spin above our heads. Yet against this backdrop, changes are taking place — often hard to see and sometimes spectacular, but always raising questions about the past and the future.

assess on

Thinking about the night sky

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. (a) What are stars and what are they made of?
   (b) What is the name of the nearest star to Earth?
2. Each of the following objects might be visible in the night sky:
   - galaxies
   - planets
   - stars
   - moons
   - constellations.

   Arrange these objects in a table from largest to smallest. Work in pairs and use your current knowledge to suggest a definition for each object.
3. Observe the stars on a dark night, preferably around the time of a new moon. Draw the positions of the ten brightest stars and label your diagram to indicate the colour of each.
4. While observing the night sky, you might notice stars of different brightness and slightly different colours. Can you explain why?
5. Explain why the positions of stars change over the weeks and months.
6. What is a light-year? Why is it a useful concept in astronomy?
7. Form a group with two or three other students that have a different star sign from your own. Ask each group member to collect their horoscope from a magazine or newspaper each week for two to three weeks. Paste yours into your workbook and record whether any of the predictions seem to match incidents in your week.
8. Astronomers believe that quasars are formed when black holes at the centre of galaxies begin to pull in gas and stars from the galaxy.
   (a) What is a black hole?
   (b) What is a galaxy?
   (c) To which galaxy does the solar system belong?
9. The photograph of the quasar at right was taken by the Hubble Space Telescope.
   (a) Where is the Hubble Space Telescope?
   (b) Why are the photographs taken by the Hubble Space Telescope clearer than those taken by larger telescopes on the Earth's surface?
10. How do we know so much more about the distant parts of the universe now, in the twenty-first century, than what we knew about 400 years ago when people were arguing about whether the Earth or the sun was the centre of the universe?
11. Given that the Earth is such a tiny speck in the universe, would you expect to find other, similar planets in the universe? Explain.

The quasar PG 0052+251 is 1.4 billion light-years away. That is, when you look at its image, you are seeing it as it was 1.4 billion years ago.

The Hubble Space Telescope. Even though it is much smaller than many telescopes on the ground, it can 'see' much further into the universe.

INVESTIGATION 10.1

Light pollution

AIM: To model the effect of light pollution on the visibility of stars

You will need:

2 sheets of A4 paper
pen
sticky tape
torch

- Prick holes in a sheet of A4 paper using the tip of a pen to model the five stars of the Southern Cross (see Stars around the Southern Cross in Investigation 10.5).
- Stick this sheet of paper over another sheet and tape them both to a window so that daylight shines through them.
- Record your observations.
- Now shine a torch over the stars and record any changes that you observe.

Discussion

1. What effect did shining the torch have on the visibility of the stars?
2. Explain what this investigation demonstrates about when and where astronomers can observe celestial objects.

10.2 Stars and constellations

10.2.1 The brightness of stars

Many stars in the night sky are visible to the naked eye. One of the brightest celestial (sky) objects is in fact not a star, but the planet Venus. Unlike stars, planets do not produce their own light but reflect the sun's light. Stars are immense spherical masses of hydrogen gas undergoing a fusion reaction, producing helium and enormous amounts of light and heat energy.

The brightness of a star does not necessarily tell us how far away a star is. The closest star to our solar system, Proxima Centauri, was not discovered until modern telescopes were invented. It is so dim that it cannot be viewed with the naked eye. The brightest star in the sky is Sirius. It is almost twice the distance of Proxima Centauri, at 8.6 light-years from Earth, but Sirius is much larger.

Sirius, the brightest star in the night sky

The magnitude scale

Astronomers use the term 'apparent magnitude' when referring to the relative brightness of stars viewed from Earth. The magnitude scale was developed by the ancient Greeks around 150 BC. The Greeks put the stars they could see into six groups. The brightest stars were placed in group 1, and called them magnitude 1 stars. Stars that they could barely see were put into group 6. So, in the magnitude scale, bright stars have lower numbers.

Celestial object	Apparent magnitude
Sun	–26
Full moon	–12
Venus	–4.3
Sirius	–1.5
Alpha Centauri	–0.04
Delta Crucis (Southern Cross Constellation)	2.8
Proxima Centauri	11.1

Increasing brightness

Using this scale, a star that is one magnitude value lower than another star is about 2.5 times brighter. For example a magnitude 4 star is 2.5 times brighter than a magnitude 5 star and so a star that is five magnitude numbers lower than another star is 2.5^5 or 100 times brighter.

Astronomers have extended the magnitude scale at each end to include celestial objects brighter than magnitude 1 and dimmer than magnitude 6.

USING SCIENTIFIC NOTATION

Very large numbers are often written in a special way called scientific notation. This allows us to avoid writing lots of zeroes and also makes the number easier to read, because the reader does not have to count the zeroes. For example, the distance between the Earth and the sun averages 150 million kilometres. This could be written as 150 000 000 km or, in scientific notation, as 1.5×10^8 km.

Some other examples are:

- $45\,000\,000\,000 = 4.5 \times 10^{10}$
- $700\,000\,000\,000\,000\,000 = 7.0 \times 10^{17}$.

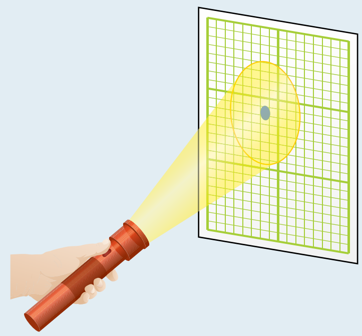
INVESTIGATION 10.2

The brightness of stars

AIM: To investigate the relationship between a star's distance and the proportion of light reaching us

You will need:

graph paper with millimetre squares
ruler
small torch



- Colour in a small circle with a diameter of about 1 cm to represent the Earth on a sheet of graph paper.
- Hold a torch, representing a star, 2 cm from the graph paper and record the diameter of the circle of light created.
- Move the torch back a further 2 cm at a time and repeat the process until the diameter of the light circle exceeds the size of the graph paper.
- Record the proportion of total light output of the star received by the 'Earth' (as a percentage) at each distance as follows:

$$\text{proportion of light recevied} = \frac{\text{diameter of Earth}}{\text{diameter of light circle}} \times 100$$

- Record all your data in a suitable table.
- Plot a line graph to demonstrate the relationship between the distance from a star (*x*-axis) versus the proportion of light received on Earth (*y*-axis). Draw a line of best fit.

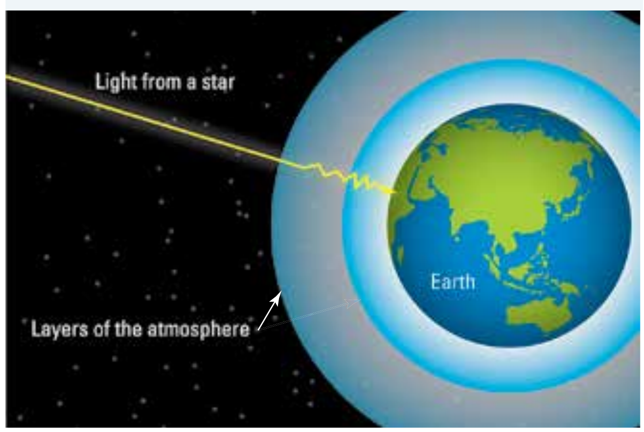
Discussion

1. This investigation models the effect of distance on the brightness of stars viewed from Earth. Write a suitable conclusion for this investigation.
2. What benefits does modelling have in science?

10.2.2 Twinkling stars

Stars appear to 'twinkle' in the night sky. This is because the light travelling from a star is distorted by the Earth's atmosphere. The light is bent in all directions as it passes through the moving air of the atmosphere. This causes the image to change slightly in brightness and position and hence twinkle. This is one of the reasons the Hubble telescope in orbit high above the Earth is so successful at capturing clear images of celestial objects. In space, there is no atmosphere to make the stars twinkle, allowing a much clearer image to be obtained.

Pockets of warm and cold air in the Earth's atmosphere bend light from a star, making the star appear to twinkle.



INVESTIGATION 10.3

Twinkling stars

AIM: To model the twinkling of stars

You will need:

aluminium foil
glass dish
torch

- Fill a glass dish with water.
- Take a sheet of aluminium foil large enough to cover the base of your dish.
- Crinkle the foil into a loose ball then open it out again.
- Put the crinkled foil under the glass dish.
- Darken the room and then shine a light down at an angle into the dish while the water is still. Observe the reflected image.
- Stir the water and, while it is still moving, shine the torch into the dish and once again observe the reflected image.

Discussion

1. What effect did the turbulence of the water have on the image of reflected light?
2. How do these results help explain why stars twinkle?

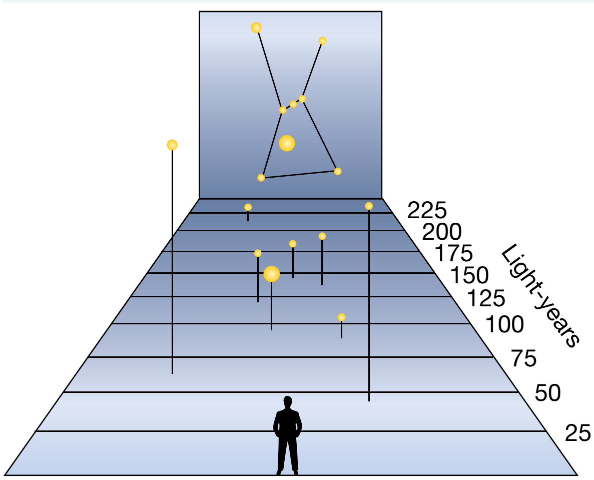
10.2.3 Constellations

Astronomers of ancient civilisations grouped stars according to the patterns or shapes they seemed to form. These shapes were usually of gods, animals or familiar objects. Today, astronomers divide the sky into 88 regions of stars. The group of stars within each region is called a constellation.

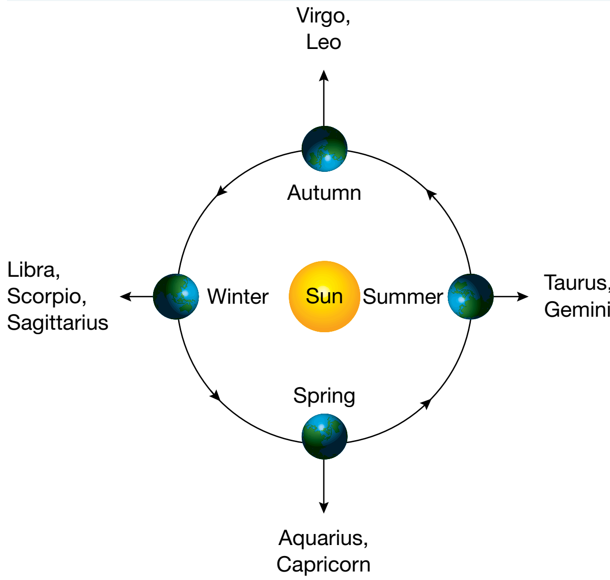
When viewed from Earth, the individual stars in a constellation may appear to be very close to each other. However, they can be separated by huge distances in space and in fact have no real connection to each other at all. The stars that make up the constellation Orion, for example, are at very different distances from Earth.

The constellations visible on any given night depend on the time of year. For example, Gemini and Leo are clearly visible in March but not in October.

The distances to stars in the constellation Orion from Earth



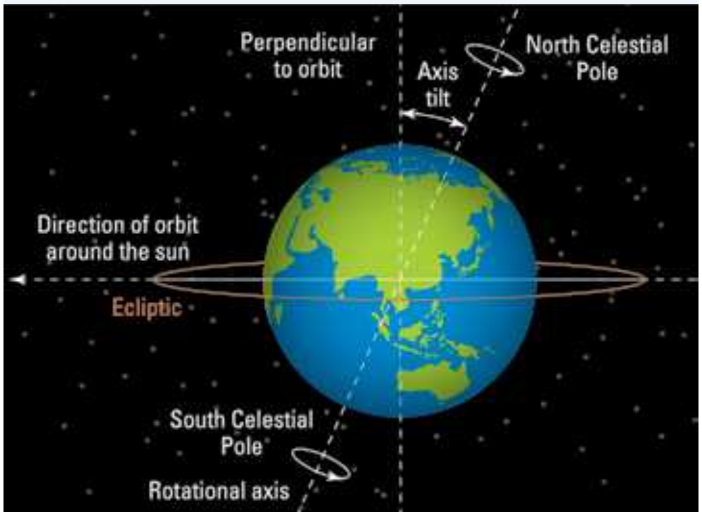
The constellations that are visible depend on the position of the Earth in space.



In ancient times, it was thought the stars wandered through the night sky; today we explain the stars' apparent movement in terms of the motion of the Earth through space as it orbits the sun.

Over the course of an evening, the positions of constellations appear to move from east to west. This is due to the Earth's spin. Just like the sun and the moon, stars rise in the east and set in the west. A time-lapse photograph of the stars taken over several hours shows the changing positions of the stars due to the Earth's spin. The central point around which the star trails appear to rotate is called the South Celestial Pole and it indicates the Earth's axis of rotation.

Stars appear to move around the celestial poles due to the spin of the Earth.

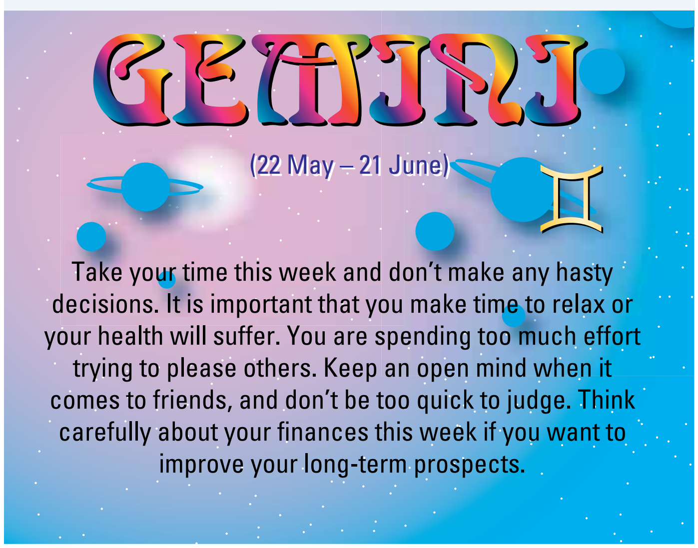


Star trails produced by time-lapse photography

The zodiac

Twelve constellations pass through what is known as the **ecliptic**, the path that the sun traces in the sky during the year. Ancient Greek astronomers believed that these twelve constellations had a special significance and are known today as the constellations of the **zodiac**.

A horoscope prediction for a 'Gemini' — someone born between 22 May and 21 June



INVESTIGATION 10.4

Star charts

AIM: To observe the relative motion of the moon and stars over a period of time

- Observe one night when the moon is visible and try to find some stars that appear close to the moon.
- Sketch the positions of the moon and nearby stars.
- Observe again one or two nights later at the same time and compare your previous drawing with what you see.
- Observe again a few weeks later at the same time and compare your original drawing again with what you see.

Discussion

1. The stars you drew should be in about the same position a few nights later, but the moon will have moved. Explain why, in terms of the motion of the moon.
2. When viewed a few weeks later, the stars are in a slightly different part of the sky. Explain why, in terms of the motion of the Earth.

INVESTIGATION 10.5

Using a sky map

AIM: To use a sky map to identify and locate celestial objects in the night sky

A sky map, sometimes called a star chart or star map, shows the positions of planets, stars and constellations visible in the night sky from a given location at a certain time of the year. Use the **Star maps** weblink in the Resources section to find and print a map of the stars for the current month of the year.

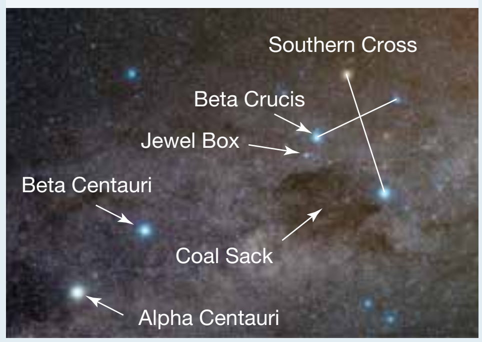
A key is provided with most star maps to indicate whether the celestial object viewed is a planet, star or other object. The brightness of stars is indicated by the diameter of the circle depicting them. A magnitude scale is used to compare the brightness of stars; brighter stars such as the Southern Pointers have a low magnitude value while fainter stars have a larger magnitude value.

You will need:

star map for the Southern Hemisphere for the current month
small torch (preferably with red cellophane taped over the end)
pair of large binoculars or a telescope (optional)
highlighter pen

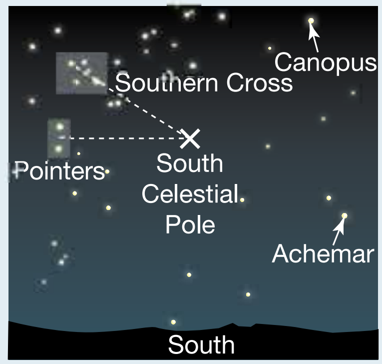
- Select a clear night, preferably with little moonlight.
- Once you have selected a viewing position, you might like to lie down and turn the chart so that the direction you are facing (north, south, east or west — use a compass if you are unsure) is shown at the bottom of the map. The centre of the chart represents the point directly above your head, called the zenith point, and the outer circular edge represents the horizon.
- Use the small torch to view your star map at night.
- Find the Southern Cross constellation and the two nearby Pointers, Alpha and Beta Centauri. There are many stars forming a cross pattern in the night sky; the key to finding the Southern Cross is locating the pointers alongside.
- If you have a pair of large binoculars or a telescope, locate and view some prominent celestial objects near the Southern Cross.
  - Alpha Centauri, at 4.3 light-years away, is the closest star visible to the naked eye in the night sky.
  - The Coal Sack is a dark patch in the Milky Way between the two brightest stars of the Southern Cross (Alpha and Beta Crucis). This is a dark cloud of gas about 60 light-years across and 500 light-years away that blocks our view of the stars in the Milky Way behind it.
  - The Jewel Box is a bright cluster of stars on the edge of the Coal Sack and near Beta Crucis. It gets its name from the various colours visible when the stars are viewed through

Stars around the Southern Cross



a telescope. The Jewel Box contains about 50 bright stars, all of which are only a few million years old. It is about 25 light-years across and about 7700 light-years away.

- Locate the approximate position of the South Celestial Pole by following the line of the long arm of the Southern Cross and finding where it intersects with a line perpendicular to the line joining the two Pointers.
- Locate as many constellations and other prominent celestial objects as possible.
- Highlight each of the constellations on your sky map once you have viewed them.



10.2 Exercise: Remember and think

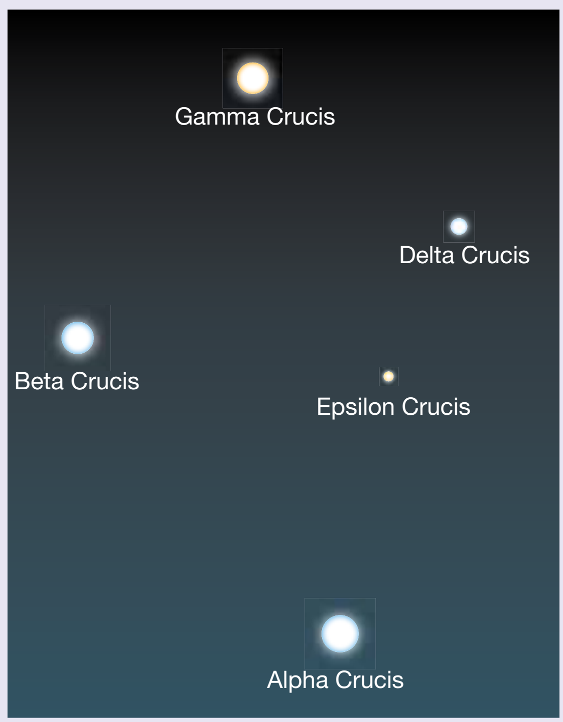
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What are stars? How are they different to planets?
2. **Explain** why stars appear to twinkle.
3. **Define** the term 'constellation'.
4. There are 88 named constellations. What is special about the 12 constellations of the zodiac?
5. **Explain** why different constellations are visible in different months of the year.
6. **Explain** why the positions of stars appear to change over the course of an evening.
7. **Define** the term 'South Celestial Pole' and **describe** how it can be found.

Think

8. **Explain** why so many more stars are visible in the night sky in rural areas than in the city.
9. **Explain** why stars, apart from the sun, are not visible during the day.
10. In investigation 10.5 it was suggested that the torch should be covered in red cellophane. **Explain** why.
11. Refer to a star map to **identify** a:
    (a) star of magnitude 0
    (b) constellation along the ecliptic
    (c) planet that should be visible.
12. The five main stars of the Southern Cross constellation are shown on right. All five stars appear to be the same distance from the Earth but they are not.
    The brightness of each star and its actual distance from Earth are listed in the table below.



Star	Distance from Earth (light-years)	Brightness (magnitude value)
Alpha Crucis	321	0.8
Beta Crucis	353	1.3
Gamma Crucis	88	1.6
Delta Crucis	364	2.8
Epsilon Crucis	228	3.6

(a) **Identify** the star closest to the Earth.
(b) **Identify** the brightest star.
(c) Beta Crucis and Gamma Crucis have a similar brightness when viewed from Earth. **Identify** which star emits more light and **justify** your response.

Calculate

13. It takes 8 minutes for light from the sun to reach the Earth. If light travels at 300 000 km/s, **calculate** the distance of the sun to the Earth in kilometres.
14. The distances to some prominent celestial objects are listed below. Copy the table and **calculate** the time it would take a space probe to travel from Earth to each destination if travelling at a speed of 6 km/s (using current technology) as follows:

$$\text{time taken by space prode} = \text{time taken by light} \times \frac{300\,000 \text{ km/s}}{6 \text{ km/s}}$$

Destination	Time taken by light	Time taken by a space probe
Moon	1.3 seconds	_____ seconds
Mars (at its closest point in orbit)	3.1 minutes	_____ minutes
Sun	8.3 minutes	_____ minutes
Alpha Centauri (the closest star visible in the night sky)	4.3 years	_____ years
Sirius (the brightest star in the night sky)	8.7 years	_____ years
Large Magellanic Cloud (a galaxy close to the Milky Way)	179 000 years	_____ years

15. Match each constellation to the correct representation on the sky map by completing the **Star matching** interactivity in the Resources tab.
16. Use the **Star maps** weblink in the Resources tab to print a map of the stars for any month of the year.

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Try out this interactivity: Star matching (int-0232)
Explore more with this weblink: Star maps
Complete this digital doc: Worksheet 10.1: Observing stars (doc-12797)

10.3 The life cycle of stars

10.3.1 A star is born

Movie stars come and go. Some have brief careers while others seem to go on forever. It's very much the same with the stars in the sky. Stars come and go — they don't last forever.

Dust and gas are not evenly distributed in interstellar space. Some regions of the universe contain denser concentrations of swirling dust and gas. Within these currents, the density sometimes reaches the critical figure of 100 atoms per cubic centimetre. At this point, gravity takes hold and the gas and dust begin

A star-forming region in the Carina nebula captured by the orbiting Chandra telescope. In this image, the blue hues indicate regions emitting high energy X-rays and red regions are associated with lower energy X-rays.

to collapse into the beginnings of a new star. The collapse continues under the influence of gravity, forming visible clumps in a nebula cloud. As the clumps collapse further, the original gas cloud begins spinning at ever-increasing speed. At the same time, the increasing pressure causes the temperature to rise and the conditions are right for a star to be born.

These clouds of interstellar matter are called nebulae and could be considered star 'nurseries'.

INVESTIGATION 10.6

Heat produced by compressing a gas

AIM: To model the heat generated when stars form

You will need:

a bicycle pump
a bicycle tyre

- Using an energetic pumping action, inflate a tyre with the bicycle pump. Alternatively, just pump the bicycle pump with your finger partially covering the open end so the air does not escape.
- Now feel the body of the pump.

Discussion

1. What change has been observed?
2. How does an increase in air pressure affect the temperature of the surroundings?
   (The opposite effect can be observed when carbon dioxide gas is released from a soda bulb.)
3. How does this activity model star formation?

10.3.2 The young, the old and the dead

A quick glance around the night sky shows us that stars differ quite noticeably from one another, both in how bright they appear to us and in their colour (see Investigation 10.8). Some of them are relatively close to the Earth, while others are much further away. There are young stars, middle-aged stars like the sun, old and dying stars and exploded stars. By collecting details of a wide range of stars, we can trace the various stages in the development of typical as well as unusual stars. This is like looking at the characteristics of hundreds of people and using patterns in the data to draw conclusions about the life of one individual.

10.3.3 Star light, star bright

The apparent magnitude of a star is a measure of how bright it appears from Earth and is the result of the star's distance from the Earth and how much light it emits. The amount of light a star emits is referred to as its 'absolute magnitude' and determined by the star's:

- size: larger stars tend to be brighter
- surface temperature: brighter stars tend to have a high surface temperature and are white in colour, while cooler stars are red and less bright.

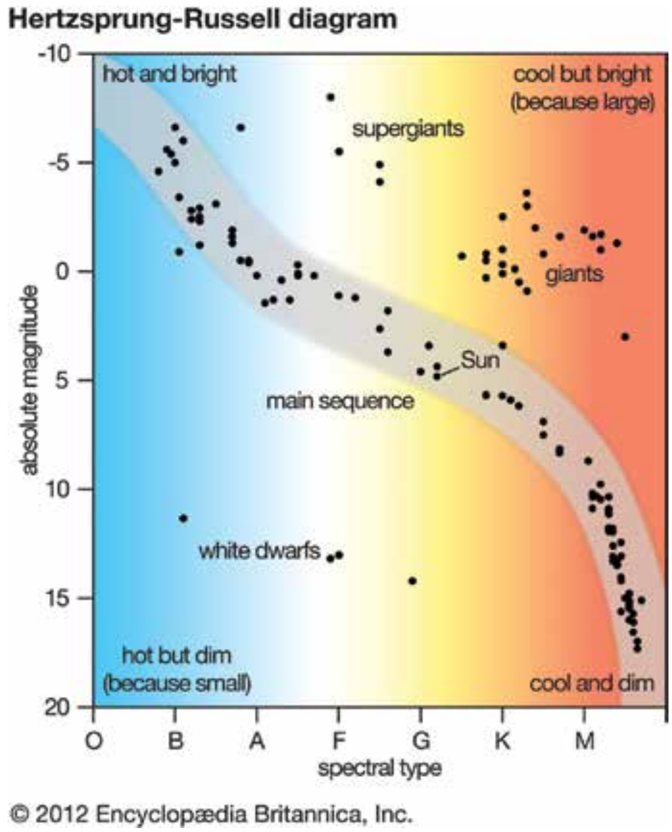
The interplay between these two features determines the rate of light output of a star and hence the actual brightness of a star. For example, Betelgeuse is a bright star due to its large size even though it is a relatively cooler red star.

A dim star close to us may appear brighter than a really bright star a long way away. To calculate the absolute magnitude of a star, astronomers must know how far away it is.

An interesting way of displaying the data collected about stars was developed independently by two astronomers, Ejnar Hertzsprung from Denmark and Henry Norris Russell from America. This diagram has now been named after both of them. In the Hertzsprung–Russell diagram, the absolute brightness of a star is plotted against its surface temperature, which is deduced from its colour. When data for many stars is plotted, most of them, including our sun, fall into a group known as the **main sequence**. Exactly where a star is found along the main sequence is determined by its mass. Low-mass stars tend to be cooler and less bright than high-mass stars.

Other types of star show up very clearly on the Hertzsprung–Russell diagram but in much smaller numbers than in the main sequence. The names of these stars — white dwarfs, red giants, blue giants and super giants — clearly describe their characteristics. Astronomers suggest that all stars begin their existence in the main sequence and spend the largest part of their life there. This explains why most of the stars observed at a particular time are in the main sequence phase. The rarer types are stars that pass relatively quickly through later stages of development on the way to extinction as their nuclear fuel runs out.

The Hertzsprung–Russell diagram sorts stars according to their absolute magnitude (or luminosity) and spectral type (which relates to the surface temperature).



INVESTIGATION 10.7

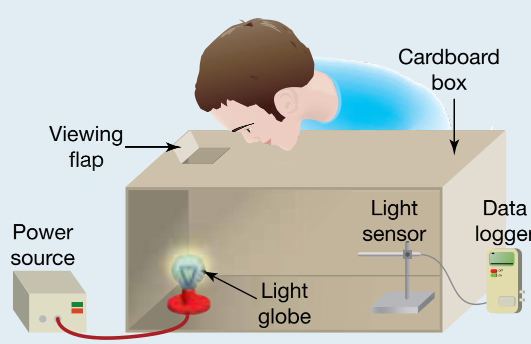
Colour and brightness

AIM: To investigate the relationship between the colour and brightness of a light-emitting object

You will need:

12 V incandescent light globe
2 wire leads
DC power source
data logger and light sensor
scissors
cardboard box (e.g. photocopy paper box)

- Cut a viewing flap and a slot for the light sensor to be placed in position.
- Connect the light globe to a power source.
- Place the box over the globe and position the light sensor in the slot of the box and a fixed distance from the globe.
- Turn the power source to 2 volts and turn it on.
- Pull back the viewing flap and through the hole observe the colour emitted by the filament and record.
- Close the viewing flap and record the light intensity indicated by the light sensor.
- Increase the voltage by 2 volt increments and repeat the experiment.
- Record all your data in a suitable table.



INVESTIGATION 10.8

Seeing the colours of stars

AIM: To observe stars within the constellation Orion

You will need:

sky map (optional)
pair of binoculars (optional)

- Use the information below, a sky map or an astronomy computer program to help you to find the constellation Orion (the Hunter). Alternatively, find a colour photograph of the constellation Orion.
  - The star α-Orionis (also known as Betelgeuse) is a red giant which has a diameter bigger than Earth's orbit. It appears red to the naked eye and this distinctive colour shows up even more clearly through binoculars. The star β-Orionis (also known as Rigel) is 60 000 times as bright as the sun.
- Compare the colours of Betelgeuse and Rigel.
- Try to locate the Orion Nebula using the following information.
  - The constellation Orion (the Hunter) is visible from every inhabited place on Earth. It is most easily recognised from the line of three stars that represent the hunter's belt. Remember, the constellations were named by observers in the Northern Hemisphere so, to southern observers, the constellations appear upside down. This is why Orion's sword points upwards from the belt. This group of stars, making up the sword and the belt, is often known as the Saucepan.
  - Orion's sword, pointing upwards from the belt, contains a misty patch visible to the naked eye. This is the Orion Nebula, labelled M42 by the astronomer Messier, who prepared a catalogue of such objects. Through binoculars, stars can be seen embedded in the gas and dust of the Orion Nebula and new stars have been seen as they begin to emit light. The Orion Nebula and other similar formations are the birthplace of the stars.

10.3.4 From cradle to grave

Stars are 'born' within nebulae from gas and dust coming together through the force of gravity. During this process, the centre of the nebula may heat up and glow. Eventually sufficient hydrogen gas may accumulate to form young stars. Stars then spend most of their life as stable 'main sequence' stars, and are powered by a fusion reaction within their core which converts hydrogen to helium. The size of a star determines how quickly the hydrogen in the core is used up. Small- to medium-sized stars like the sun have a life span of 10 billion years. The sun is currently 4.6 billion years old and in the main sequence phase, slowly consuming hydrogen gas. Beta Centauri is a larger, hotter star and, because it consumes its hydrogen at a faster rate, will reach the end of its life within a relatively short 10 million years.

Main sequence to red giants

In a stable main sequence star, hydrogen is steadily turned into helium by the process of fusion. As helium builds up in the core of the star, the remaining hydrogen forms a shell around the core. The shell gradually expands and the star swells to 200 or 300 times its original size, cooling as it does so, to become a **red giant**. This will eventually happen to our sun, which will grow large enough to swallow up the inner planets, including Earth.

In the core of a red giant, new fusion processes take place, turning helium into heavier elements such as beryllium, neon and oxygen. This increases the rate of energy production and raises the star's temperature. A sun-like star which has become a red giant might shine 100 times more brightly than it did in its stable period.

Eventually red giants collapse inwards leading to the destruction of the star. The nature of its death depends on the size of the original star.

White dwarfs

For stars less than about eight times the mass of our sun, the destruction of a red giant begins when the outer layers are thrown off into space and the core flares brightly, forming a ring of expanding gas called a **planetary nebula**. The name 'planetary nebula' is misleading because it is not related to planets. But it does have the cloud-like nature of a nebula.

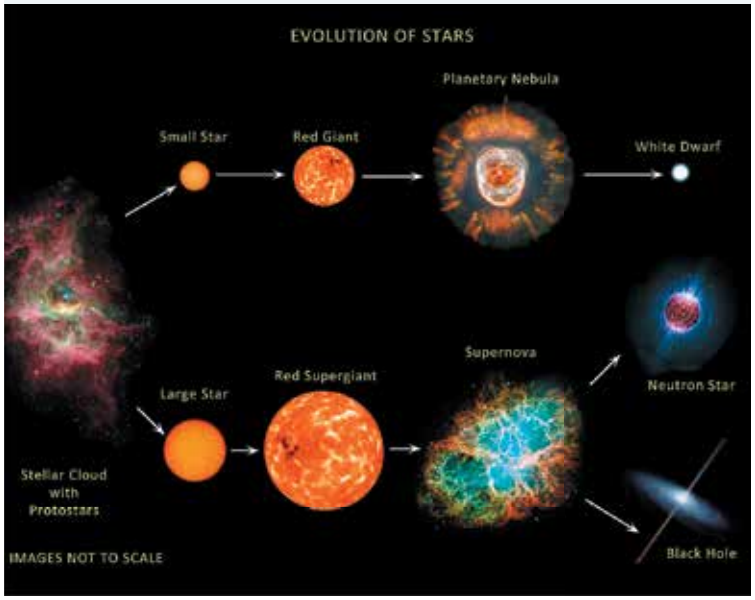
The remaining star fades to become a **white dwarf**, typically about the size of a planet like the Earth but with a very high density and a surface temperature of about 12 000 °C. It then slowly cools, becomes a cold black dwarf and disappears from view.

Coming to a violent end

Stars that are more than about eight times the mass of our sun come to a much more violent end. They swell into much larger red giants called **super giants**, then blow up in a huge explosion called a supernova. The matter making up the star is hurled into space along with huge amounts of energy. A supernova can emit as much energy in a month as the sun radiates in a million years. Observable supernova events in the Milky Way happen every 200 to 300 years on average. The supernovas fade from view within a few years. They are extremely important in the universe because it is within these violent explosions that the heavy elements such as iron and lead are produced.

What remains of a supernova is extremely dense; the pull of gravity becomes so great that even the protons and electrons in atoms are forced together. They combine to form neutrons and the resulting solid core is known as a **neutron star**. If the remaining core has a mass more than about three times that of our sun, the force of gravity is great enough to 'suck in' everything — even light. Such a core becomes a **black hole**.

Large stars follow a different evolutionary sequence to smaller stars like the sun.



10.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. (a) What are nebulae?
   (b) Why are nebulae often called 'star nurseries'?
2. **Explain** why most stars are found in the main sequence of the Hertzsprung–Russell diagram.
3. Which group of stars shown on the Hertzsprung–Russell diagram does the sun belong to?
4. **Describe** how a red giant becomes a white dwarf.
5. **Explain** why the term 'planetary nebula' is a misleading way to describe the ring of expanding gas thrown out by a red giant during its transformation into a white dwarf.

Using data

6. The table at right lists information about three bright stars. Use this information to **identify**:
   (a) which star emits the most light
   (b) which star is the faintest as seen from Earth.

Star	Apparent magnitude	Absolute magnitude
Rigel (Orion)	+0.11	–7.5
Aldebaran (Taurus)	+0.86	–0.3
Canopus (Carina)	–0.73	–4.6

Think

7. Is it likely that our own star, the sun, will become a supernova? **Explain** your answer.
8. **Describe** what the night sky would look like if you had eyes that could ‘see’ like the *Hubble Space Telescope*.

Investigate

9. **Research** the formation and destruction of a supernova. For example, when was the last supernova seen? Can we predict when the next one will be seen?
10. Test your knowledge on the life of a star by completing the **Star cycle** interactivity in the Resources tab.

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- **Try out this interactivity:** Star cycle (int-0679)
- **Explore more with this weblink:** Stellar evolution
- **Complete this digital doc:** Worksheet 10.2: Star life cycles (doc-12798)
- **Complete this digital doc:** Worksheet 10.3: The brightness of stars (doc-12799)
- **Complete this digital doc:** Worksheet 10.4: The sun and nuclear fusion (doc-12800)

10.4 The Milky Way and beyond

10.4.1 The Milky Way galaxy

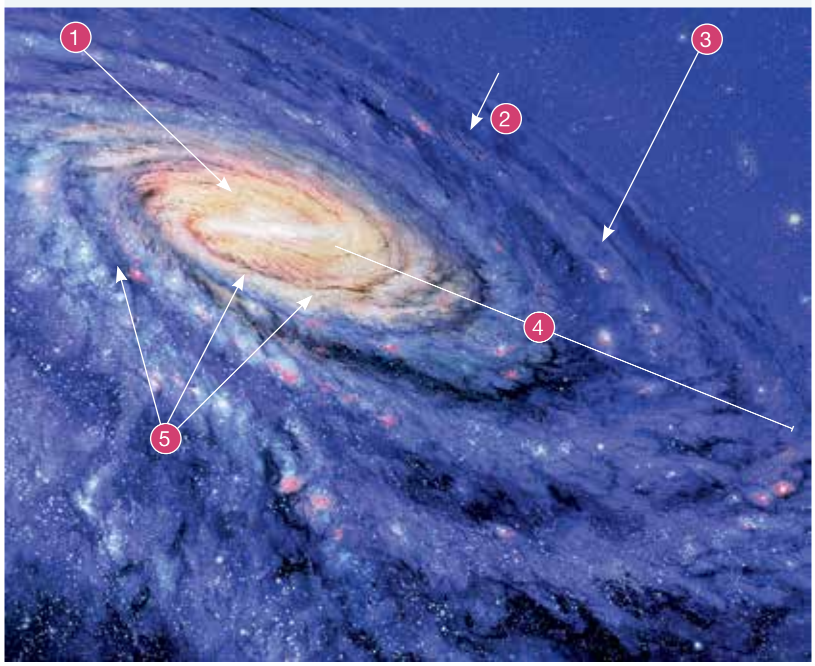
The sun is the closest star to the Earth. It formed about 4.5 billion years ago from a cloud of dust and gas making up a nebula. The Earth and our neighbouring planets formed from leftover nebula materials soon after the sun gases started to clump together. This marked the birth of our solar system.

Stars group together to form galaxies, which are bound by gravitational forces. Our sun is one of the 200–400 billions of stars within the Milky Way Galaxy. We know of about 100 billion more galaxies of different shapes and sizes throughout the universe. Each of these galaxies is home to stars at all stages of their life cycles, including those undergoing violent explosions, known as supernovas.

The Milky Way Galaxy (shown right) is a spiral galaxy with a radius of 50 000 light-years. Our solar system is found on the Orion arm of the spiral.

Due to the rotation of the galaxy, our solar system orbits the centre of the galaxy at a speed of about 200 kilometres per second! Scientists believe that, since its birth, our solar system has travelled around the centre of the galaxy up to 20 times.

An artist’s impression of the Milky Way. The Milky Way, along with our neighbouring galaxy, the Large Magellanic Cloud, forms part of the Local Group of galaxies.



1. Possible **black hole** in centre
2. Areas of glowing pink, blue and green gas are **nebulae** where new stars form.
3. Approximate location of our **solar system** on the Orion arm of the Milky Way
4. 50 000 light-years
5. Spiral arms

While we are most familiar with the gravitational force of the Earth and of the gravitational pull of the Moon affecting the Earth's tides, we have just read that the sun, the solar system and galaxies are all formed and influenced by gravitational forces. In fact everything in the universe, from the smallest speck of dust to supermassive black holes, exerts the force of gravity on other objects. It is the interaction of the gravitational forces of all objects that first drew gases in the early universe together to form stars. It was the gravitational forces of those stars that drew stars together to form galaxies. It is the gravitational force between all objects in the universe that is responsible for the formation of stars, planets, solar systems and galaxies.

Light-years away

The universe is so big it is difficult to comprehend its size. It would take light almost 14 billion years to reach the most distant objects in the universe.

The closest star to our solar system that is visible to the naked eye, Alpha Centauri, is about 41 000 billion kilometres away. The distances between objects in the universe are so vast that expressing them in kilometres would involve immense numbers. Instead, astronomers use a much larger unit of distance, the **light-year**. A light-year is the distance that light travels in one year. If light travels 300 000 km per second, then in one year it travels 300 000 × 60 s/min × 60 min/h × 24 h/day × 365.25 day/yr = about 9500 billion kilometres. This means that Alpha Centauri is 4.3 light-years away.

When we look at the stars, we see the light produced by them. However, because of the vastness of space, that light takes a long time to reach us here on Earth. So, in fact, viewing stars is like looking back in history; the light we see today from Alpha Centauri was emitted 4.3 light-years ago. The Andromeda Galaxy is the most distant object visible to the human eye; at 2.2 million light-years away we are looking at the light it released 2.2 million years ago, before the appearance of modern humans, *Homo sapiens*.

Galactic shapes

American astronomer Edwin Hubble recognised that galaxies could be grouped according to their shapes.

Spiral galaxies, like the Milky Way and Andromeda galaxies, rotate. They have a bright bulging middle with two or more curved arms of stars spiralling out from the centre. The middle parts of spiral galaxies spin faster than the edges. The older red stars are found closer to the centre and the younger blue stars are located on the outer arms of the spiral.

An illustration showing the relative sizes and location of the Large and Small Magellanic clouds, the two closest galaxies to the Milky Way

M87 is an elliptical galaxy. Unlike spiral galaxies, the stars in elliptical galaxies move in different directions. M87 has grown to an enormous size by pulling in other galaxies.

Irregular galaxies have no definite shape and tend to have very hot, new stars mixed in with lots of dust and gas. The Magellanic clouds are two small, irregular galaxies that look like two fuzzy clouds visible near the Southern Cross constellation. The Large Magellanic Cloud, at a distance of 160 000 light-years, is the closest galaxy to our own Milky Way Galaxy.

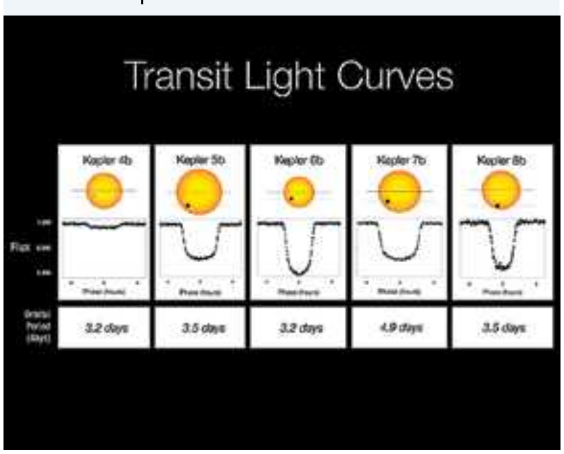
A computer-simulated view of a cluster of galaxies far from our own Milky Way Galaxy

The two Antennae galaxies colliding. During this collision, billions of stars will be formed. They give us a preview of what may happen when our Milky Way Galaxy collides with the neighbouring Andromeda Galaxy in several billion years.

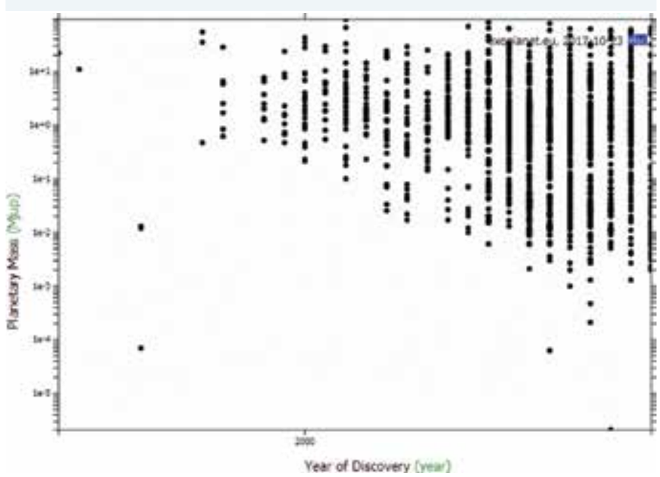
10.4.2 Searching for other planets

As the sun is just one of over 200 billion stars in the Milky Way Galaxy alone, and with billions of galaxies beyond our own in the universe, one would think the likelihood of there being other planets like our own would be high. In fact astronomers have so far discovered over 840 exoplanets, or planets beyond our solar system in a total of around 660 star systems. This may not be as many as one would expect given the tremendous size of the universe. One reason for this is that distant planets are difficult to detect as they are tiny compared to stars and are dim as they do not produce their own light. In 1995 astronomers discovered the first planet beyond our solar system by detecting the wobble back and forth on its parent star due to the gravitational pull from the orbiting planet. Other planets have been discovered by detecting a regular dip in the light intensity observed from stars as the orbiting planet passes in front of it.

Many exoplanets are detected by monitoring the drop in brightness of the stars around which the planet orbits.



The exoplanets discovered so far plotted against their size relative to the mass of Jupiter, the largest planet in our solar system. Most of the planets discovered so far are of a size similar to Jupiter.



10.4.3 Nebulae — stellar nurseries

In the photograph of the constellation Orion below right, there is a cloudy-looking, pink region. This is the Orion Nebula, known as M42. It looks small, but it is about 30 light-years across.

A nebula is an interstellar cloud of dust and gas. They are considerably smaller than a galaxy and in some nebulae, such as the Orion Nebula, they are regions of star formation. Planetary systems may form from the remaining dust.

Not all nebulae glow. Some of them absorb light from nearby stars and appear as dark spots in the sky. One of these dark nebulae can be seen in the Southern Cross constellation as a dark patch to its lower left. It is known as the Coal Sack.


The constellation Orion. Part of this constellation is also commonly known as the Saucepan.

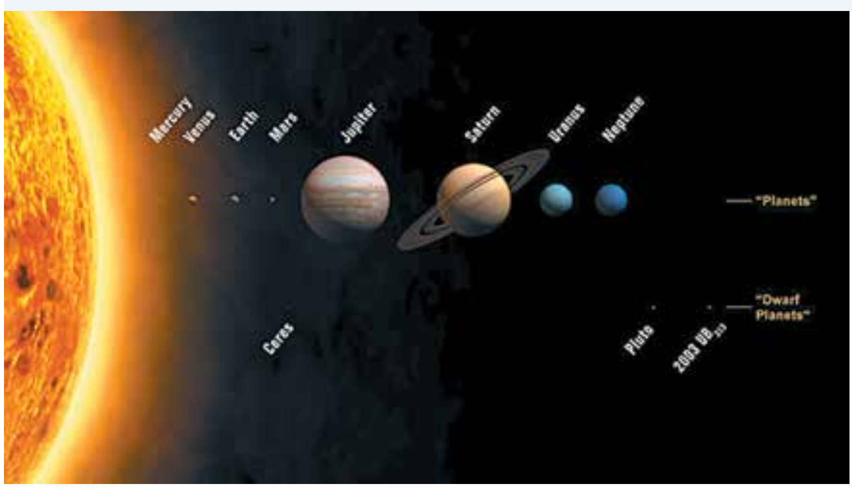

The Southern Cross and the Pointers. The Coal Sack Nebula is the dark patch to the lower left of the Southern Cross.


The Eagle nebula, often called the ‘pillars of creation’. Within this region of dust and gas, new stars are forming.

10.4.4 Size and scale of the universe

The universe is so large, it is difficult to comprehend the size and scale of the varied structures making up the universe. To begin with, the solar system consists of 8 planets and several dwarf planets, including Pluto. The distance to the outermost planet, Neptune, is 4.2 light-hours while the distance to the nearest star, Proxima Centauri, is 4.2 light-years or almost 9000 times farther away.

There are numerous stars within 10 light-years of the sun including Proxima Centauri, Alpha Centauri and Sirius. Their close proximity



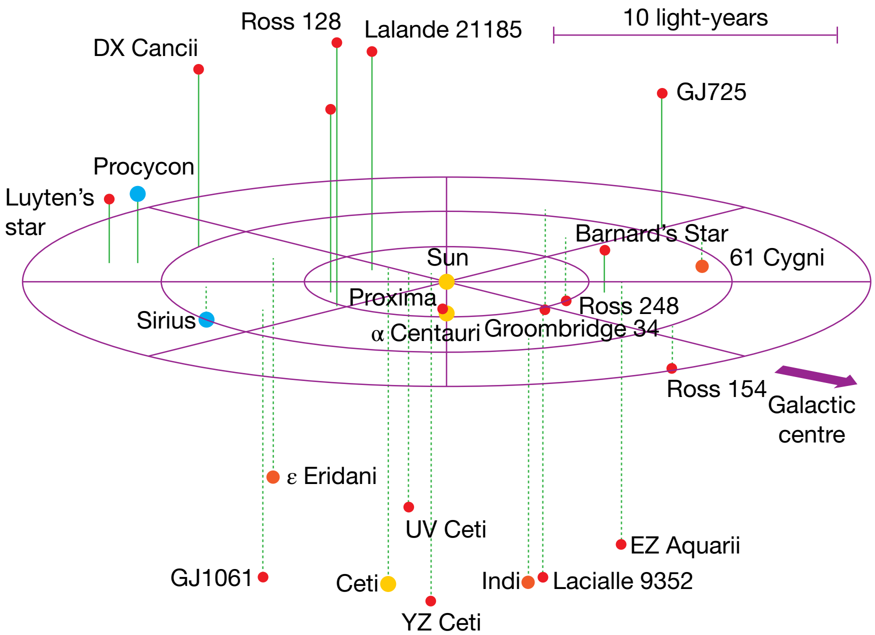
The solar system, including the major planets and dwarf planets. The size of the sun and planets are to scale but not the distances between them.

generally means that they are the brighter stars in the night sky. These neighbouring stars generally move with the sun in its orbit around the centre of the Milky Way Galaxy.

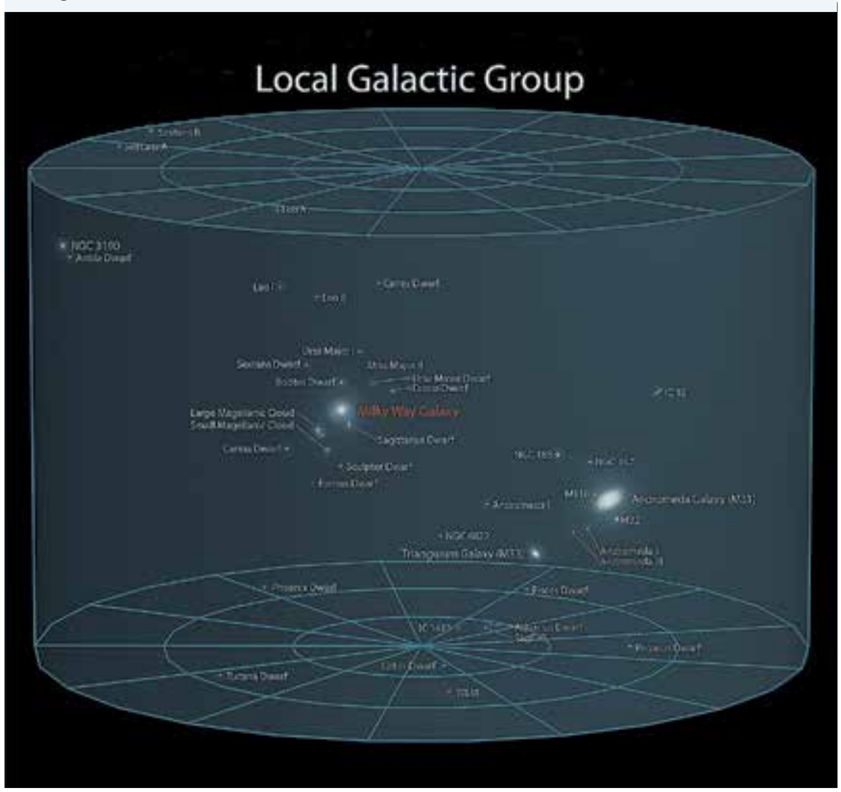
As illustrated earlier, the sun and neighbouring stars are located on the Orion arm of the Milky Way, a spiral galaxy with a diameter of 100 000 light-years. The illustration below right shows our local galactic neighbourhood, called the Local Group, is a collection of more than 30 galaxies within approximately 4 million light years of the Milky Way and gravitationally bound together. Two spiral galaxies, the Milky Way and Andromeda, are the two largest members of the Local Group. which also includes many dwarf galaxies such as the Magellanic clouds.

Telescopes able to peer into the farthest reaches of the universe reveal a web-like structure to the universe with clusters of galaxies surrounded by voids of low-density matter, mainly of hydrogen containing no galaxies. The observable universe is 27 billion light-years in size and contains more than 100 billion galaxies!

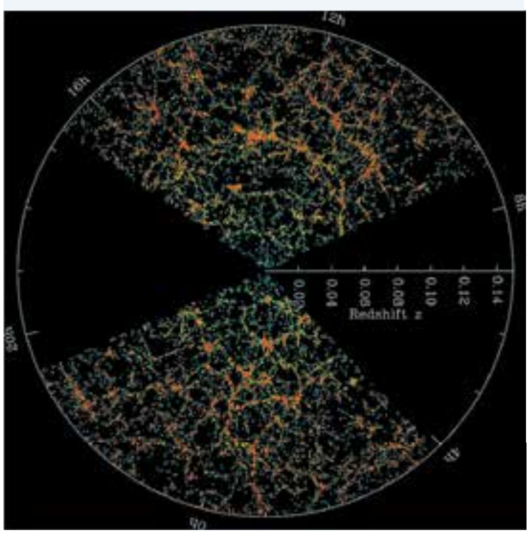
Our neighbouring stars, located within 10 light-years of the sun



The solar system and Milky Way Galaxy in relation to our Local Group of galaxies



The plane of the Milky Way Galaxy obscures our view of what lies beyond. This creates the wedge-shaped gaps in all-sky galaxy surveys such as those shown here. These surveys indicate a clumped distribution of galaxies.



INVESTIGATION 10.9

The scale of the universe

AIM: To develop a scale that models the distances in the universe

You will need:

trundle wheel (if available)
Blu-Tack

- Make 9 large cardboard labels, one for the Earth and one for each celestial object listed below.
- Copy the table below and calculate the relative distance from the Earth to each celestial object assuming a scale:

1.0 m = 1000 light-years
So that 1 cm = 10 light-years

The first distance has been calculated for you.

Celestial object	Distance from Earth	Relative distance from Earth
Neptune (the outermost major planet of the solar system)	4.0 light hours	<1 mm
Proxima Centauri (nearest star to Earth)	4.2 light-years	
Sirius (brightest star in the night sky)	8.7 light-years	
Rigel (brightest star of the constellation Orion)	780 light-years	
Orion Nebula (closest star forming nebula to Earth)	1340 light-years	
Centre of the Milky Way	38 000 light-years	
Large Magellanic Cloud (closest galaxy to the Milky Way)	160 000 light-years	
Andromeda Galaxy (closest spiral galaxy to the Milky Way)	2 200 000 light-years	

- Blu-Tack the label of the Earth at the starting point and walk the correct scale distance to each celestial object using the trundle wheel. Blu-Tack each label at the appropriate point. If a trundle wheel is not available, assume each pace is 1 m in length. You may run out of space for the last couple of celestial objects!

Discussion

1. Were you surprised at the relative distances to any of the celestial objects?
2. Explain how this modelling exercise assists with understanding the scale of the universe.

10.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, goto your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the term 'light-year' and identify the number of kilometres in a light-year.
2. **Identify** how big the universe is thought to be.
3. (a) **Identify** three types of galaxies.
   (b) Name an example of each type of galaxy.
4. **Identify** the diameter of the Milky Way Galaxy.
5. **Outline** where we are located within the Milky Way Galaxy.
6. **Identify** the force that holds the stars together within a galaxy or nebula.
7. Name the galaxy closest to our own.

Think

8. **Explain** why looking at stars is like looking back in time.
9. Arrange these astronomical objects from largest to smallest: galaxy, moon, universe, planet, star, nebula.

10. **Explain** why we can see the Milky Way in the night sky even though we are within this galaxy.
11. Write your address in the universe by stating your:
    - suburb
    - state
    - country
    - planet
    - planetary system
    - region within the galaxy
    - galaxy
    - galaxy cluster.

Using data

12. The estimated distances from Earth to some stars and galaxies are listed at right. **Calculate** how long it would take to reach each of them, travelling at the speed of light (about 300 000 km/s).

Sun	Our own star	1.5×10^{8} km
Proxima Centauri	The closest star after the sun	4.0×10^{13} km
Centre of Milky Way	Our own galaxy	2.5×10^{17} km
Magellanic Clouds	One of the closest galaxies	1.5×10^{18} km
Andromeda Galaxy	One of the closest galaxies	1.4×10^{19} km
Quasars	Very distant objects	1.4×10^{23} km

Imagine

13. **Describe** the difficulties we would have if we tried to communicate by radio with civilisations on planets orbiting even the stars closest to Earth.
14. Is it likely that a spacecraft from Earth will ever venture out to planets orbiting the closest stars? Present some calculations to support your answer.

10.5 Eyes on the skies

Science as a human endeavour

10.5.1 Smarter optical telescopes

Our understanding of the variety of celestial objects in the universe relies on astronomers' ability to make observations and to collect data from them. Galileo constructed and used one of the first telescopes in the early 1600s and with it described the crater-surfaced moon. He also discovered the moons of Jupiter which compelled him to reject the well accepted geocentric (Earth-centred) model of the universe.

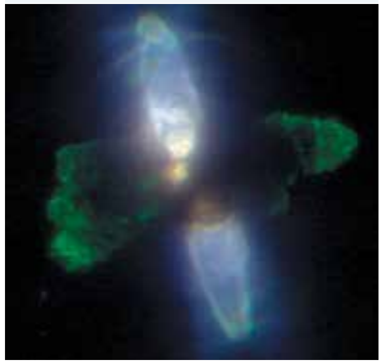
Today optical telescopes are much more sophisticated; they utilise mirrors rather than glass lenses and so are able to exceed 10 m in diameter.

The Keck I and II optical telescopes in Hawaii are amongst the largest in the world.

Large diameter telescopes have the potential to see more distant objects as they have greater sensitivity, or light-collecting capacity. Observatories are generally located at high altitude on mountain ranges to minimise the distortion of images resulting from light passing through the atmosphere, and generally far from urban centres to escape light pollution.

The Keck observatory for example is located at an altitude of 4100 m in Hawaii and consists of two 10 m optical telescopes. Even at this altitude, images of distant objects are blurred somewhat by the atmosphere. Engineers have developed a technology called adaptive optics which eliminates the image distortions by measuring and then correcting for the atmospheric effects using a deformable mirror that changes shape 2000 times per second. As a result the Keck telescopes are able to produce sharp images of celestial objects.

The formation of a planetary nebula captured by the Keck observatory. A dying star is shedding its outer layers in the final stages of its life.



INVESTIGATION 10.10

Looking for detail

AIM: To compare the resolution of optical instruments and the naked eye

Background

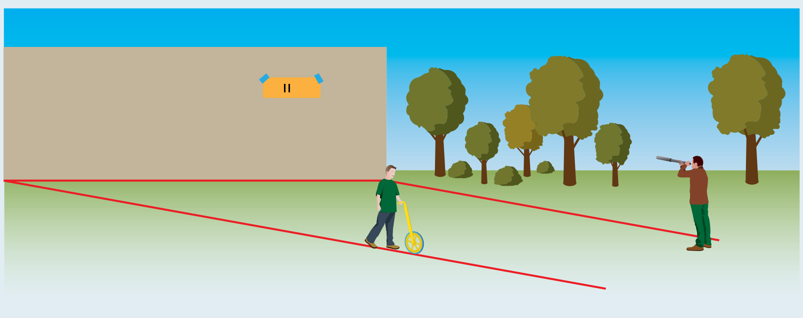
Wider diameter telescopes not only collect more light and so can see deeper into the universe but they also provide better resolution, or ability to see finer detail. Telescopes with good resolution are able to distinguish close objects in the night sky as separate and distinct.

The diameter of the lens of our eye is approximately 10 mm. In this experiment you will be comparing the resolution of the eye with optical instruments such as binoculars and the telescope.

You will need:

A4 sheet of cardboard
ruler
trundle wheel
optical telescope
thick black marker
sticky tape
pair of binoculars

- Measure and record the diameter of a lens or a mirror of the binoculars and the telescope. Record this data along with the diameter of the human eye.
- On a sheet of cardboard draw two thick black lines approximately 2 cm long and with a gap of exactly 2 mm between them. These lines represent two stars that appear close to one another in the night sky.
- Tape the sheet of cardboard to a wall or bench in open space in the playground.
- Position a member of your group as an observer, some distance from the 'stars' so that when viewed with the naked eye they appear as one single star.
- Ask the observer to slowly walk towards the stars until they appear as two separate and distinct objects. At this point, use a trundle wheel to measure the distance between the observer and the stars.
- Repeat this experiment with the assistance of binoculars and the telescope.
- Record all your data in a suitable table and present it in an appropriate graph.



Discussion

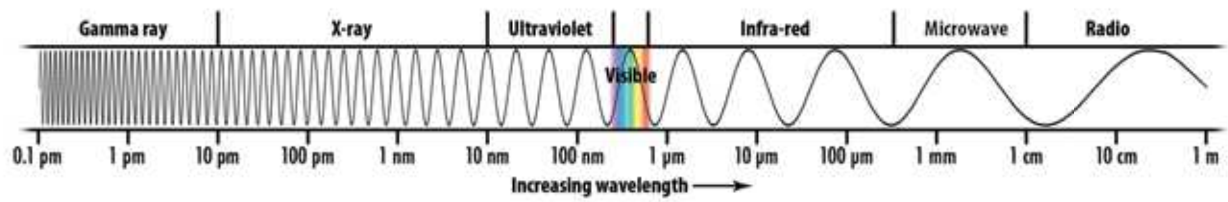
1. Which instrument provided the greatest resolution? Support your response with suitable data.
2. What advantages does a large diameter telescope provide when viewing the night sky?
3. Explain why the diameter of a telescope is not the only factor to consider when building a telescope and locating an observatory.

10.5.2 Making use of the spectrum

Relying on optical telescopes that detect only visible light would not provide astronomers with a complete picture of the universe. Many celestial objects do not emit radiation in the visible range and so would be invisible if it were not for the development of telescopes that detect other frequencies of electromagnetic radiation. For example, black holes, the remnants of large stars, do not emit visible light. However, astronomers can locate them by detecting X-rays emitted by material in the immediate environment of the black hole.

Ultraviolet light reveals hot stars and quasars while visible light allows us to image hot stars, planets, nebulae and galaxies. In the infra-red we see cool stars, regions of star birth and cool dusty regions of space. Radio waves are unimpeded by the dust in our galaxy so they can be used to detect other galaxies unable to be seen by optical telescopes behind the centre of our galaxy.

The electromagnetic spectrum



10.5.3 Detecting radio waves

Until the accidental discovery in 1931 that stars emitted radio waves as well as light, the only way to observe distant stars and galaxies was with optical telescopes. Like light and other forms of **electromagnetic radiation**, radio waves travel through space at a speed of 300 000 km per second. Radio waves from deep in space are collected by huge dishes and reflected towards a central antenna. The waves are then analysed by a computer, which produces an image that we can see. **Radio telescopes** can also detect tiny amounts of energy. In fact, the total amount of energy detected in ten years by even the largest radio telescopes would light a torch globe for only a fraction of a second. Radio telescopes can also detect signals from much further away than light telescopes can.

Unlike visible light, radio waves can travel through clouds in the Earth's atmosphere, and can be viewed in daylight as well as night. Radio waves also pass through clouds of dust and gas in deep space.

Images produced by individual radio telescopes are not very sharp. To solve this problem, signals from groups of telescopes pointed at the same object are combined to produce sharper images.

The Arecibo dish in Puerto Rico is the largest single radio telescope in the world. It is 305 m across.

10.5.4 Learning from radio waves

Many celestial objects emit radio waves but this wasn't discovered until 1932. Today, radio telescopes are used to study giant clouds of dust and gas as well as stars and galaxies. By studying the radio waves originating from these sources, astronomers can learn about their composition, structure and motion. Radio telescopes have the advantage that sunlight, clouds and rain do not affect observations.

Radio waves have, among other things, allowed us to:

- analyse the distribution of stars in the sky
- discover **quasars**, which, before 1960, were believed to be normal stars. They are like stars, but emit a lot more radiation and are travelling away from us at huge speeds. Quasars are believed to be the most distant objects in the universe.
- discover **pulsars**, which are huge stars that have collapsed, emitting radio waves. Because pulsars spin rapidly — a bit like a lighthouse — the radio waves reach the Earth as radio pulses.

The Australia Telescope Compact Array in Narrabri, rural New South Wales, consists of six 22 m dishes used for radio astronomy. The dishes work together which allows them to capture images with much finer detail, equivalent to that possible with a single radio telescope of much larger diameter.

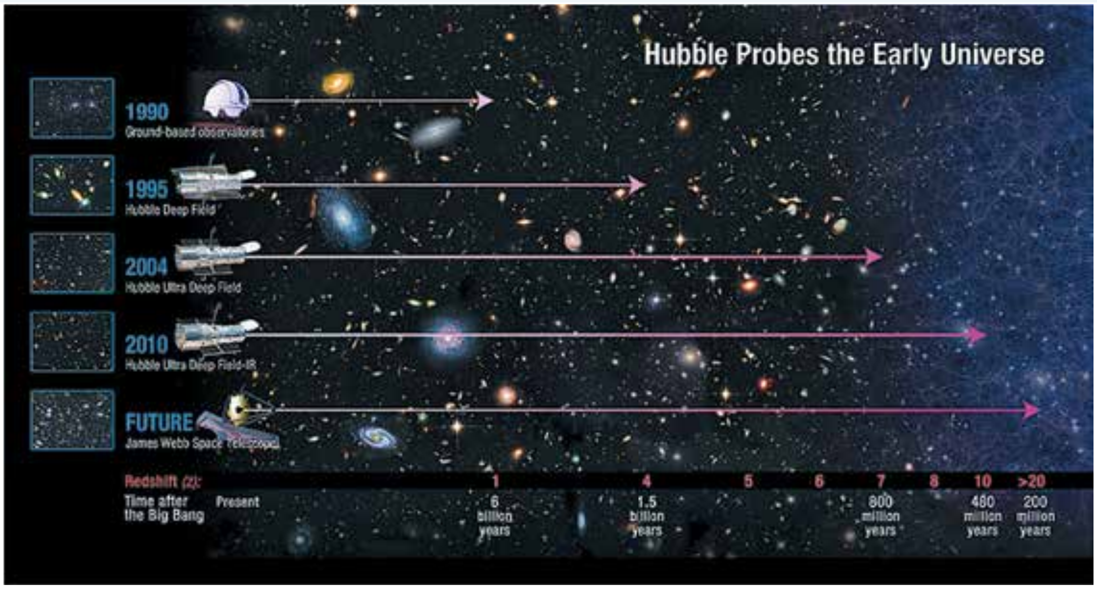
10.5.5 Space telescopes

Visible light and radio waves are the only two frequencies within the electromagnetic spectrum that penetrate the Earth's atmosphere to any large extent, allowing us to place optical and radio telescopes on the ground. The remaining types of radiation are filtered out by the atmosphere. Ultraviolet light for example is absorbed by ozone in the atmosphere. So, to place X-ray or infra-red telescopes on the ground would be fruitless. Rather, astronomers have teamed up with space agencies like NASA and the European Space Agency (ESA) to launch telescopes in orbit around the Earth (beyond the atmosphere) and within space probes travelling throughout the solar system and beyond.

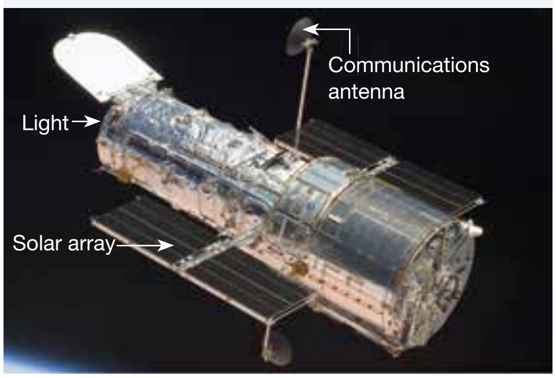
Space telescopes utilising the electromagnetic spectrum

EM radiation detected	Celestial objects studied	Space telescopes (and launch date)
Gamma rays	Supernovae, neutron stars, pulsars and black holes	• Compton Gamma-Ray Observatory (1991) • Swift Gamma Ray Burst Explorer (2004)
X-rays	Galaxy clusters, black holes and neutron stars	• Chandra X-ray Observatory (1999) • Nuclear Spectroscopic Telescope Array (2012)
Ultraviolet light	Galaxies, the sun and other stars	• International Ultraviolet Explorer (1978) • Hubble Space Telescope (1990)
Visible light	Stars, galaxies, planetary nebulae etc.	• Hubble Space Telescope (1990) • Kepler Space Probe (2009)
Infra-red light	Cooler stars (including brown dwarves), active regions of star formation and nebulae	• Spitzer Space Telescope (2003) • Hubble Space Telescope (1990) • James Webb Space Telescope (JWST) (2015)
Radio waves	Clouds of gas in interstellar space, supernova remnants such as pulsars (rapidly spinning neutron stars)	• Cosmic Background Explorer (1989) • RadioAstron (2011)

Modern space telescopes can see deeper into the early universe.



The Hubble Space Telescope is the only telescope designed to be serviced in space by astronauts. Between 1993 and 2009, five missions repaired, upgraded and replaced systems on the telescope.



The Cat's Eye nebula, a composite image utilising optical data from the Hubble Space Telescope and X-ray emissions captured by the Chandra X-ray telescope. The blue-purple hues near the nebula's centre indicate intense X-rays expelled from the dying star as it approaches the planetary nebula phase of its evolution. It is located 3000 light-years from Earth.

10.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Outline** some of the astronomical discoveries made by Galileo through the use of his early telescope.
2. **Describe** two key developments in optical telescopes that have allowed astronomers to view more distant objects more clearly from ground-based telescopes.
3. **Explain** why orbiting telescopes such as the Hubble Space Telescope provide a significant advantage when viewing distant stars and galaxies.
4. **Identify** the components of the electromagnetic spectrum from highest frequency to lowest frequency.
5. **Explain** why is it important for telescopes other than optical telescopes to be built and used by astronomers.

6. **Identify** an example of:
   (a) an X-ray telescope
   (b) a UV telescope
   (c) a radio telescope based in Australia.

Think

7. (a) **Explain** why the location of the Sydney observatory, near the centre of the city, is not optimal for astronomical viewing.
   (b) With this in mind, why would it have been built there?
8. On the weekend Sally sampled two telescopes that she was thinking of purchasing. With telescope A she could distinguish the two stars in a binary system 25 light-years away, while looking through telescope B, they seemed to be a single star. However, with telescope B she could see a nebula 50 light-years away while through telescope A the same area looked pitch black. **Compare** these two telescopes using the terms resolution and sensitivity.
9. **Explain** why X-ray telescopes and UV telescopes are placed in orbit rather than based on the ground.
10. What type of telescope would astronomers use if searching for a:
    (a) black hole
    (b) region of star formation within a nebula
    (c) cool star.

Using data

11. How long would it take visible light to travel from our nearest neighbouring star, Proxima Centauri, 4.2 light-years away to an optical telescope on Earth?

Investigate

12. Create a poster or multimedia presentation to showcase the Hubble Space Telescope. The purpose of your presentation is to **describe** the history of the program, the key astronomical findings and to **justify** the billions of dollars involved in building, launching and supporting the orbiting space telescope.

learnon RESOURCES — ONLINE ONLY

Complete this digital doc: Worksheet 10.5: Telescopes (doc-12801)

10.6 The evolving universe

Science as a human endeavour

10.6.1 The big bang

Has the universe always existed, or does it have a beginning and an end? If there was a beginning to the universe, how did it come into being? The study of the origins and evolution of the universe is called cosmology.

The ‘big bang’ is the most widely accepted theory for the origin and evolution of the universe. In the big bang theory, the universe is thought to have come into existence about 13.7 billion years ago, creating time and space.

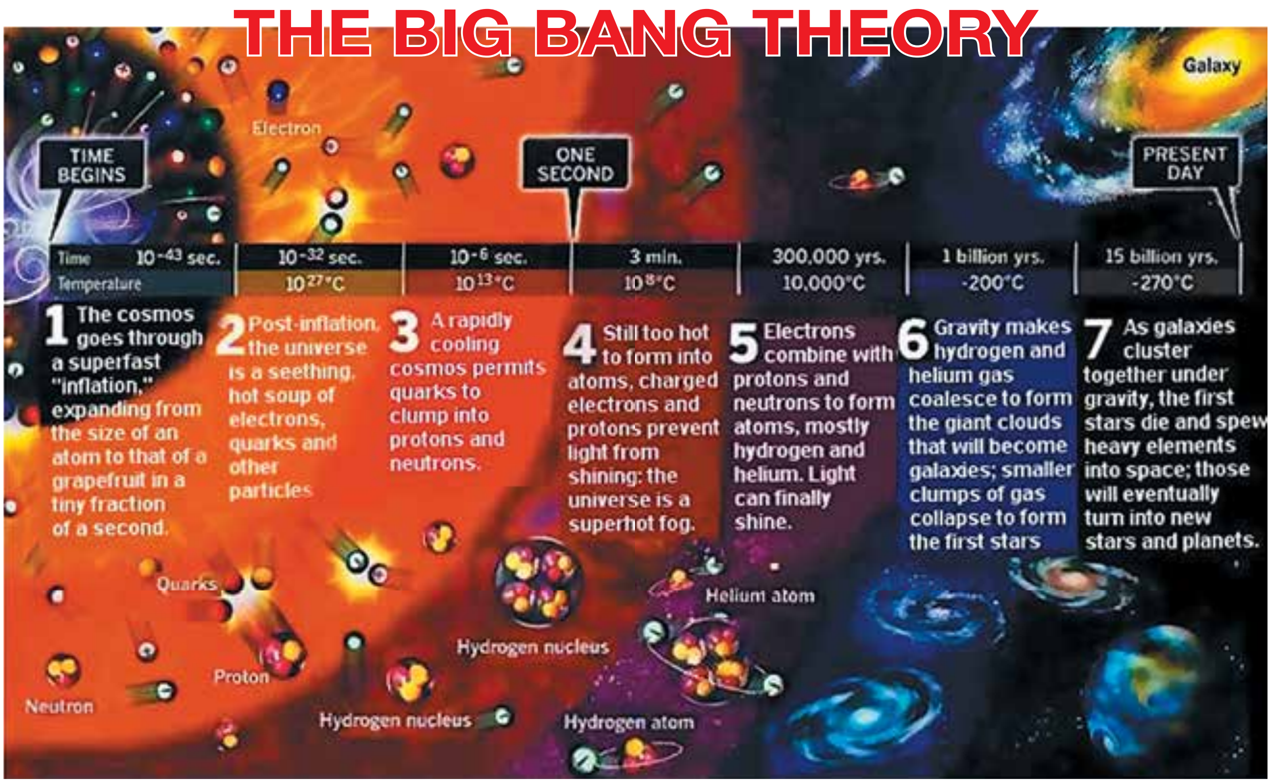
According to the big bang theory, in the beginning the universe was thought to have been concentrated into a single point of immense energy. An explosion within the first split second converted some of this energy to the simplest form of matter — particles such as quarks which are the building blocks of protons and neutrons. Over time, the universe expanded and cooled and more complex matter, such as hydrogen atoms, was formed. Stars formed from the gravitational attraction of hydrogen leading to the development of the complex universe we observe today.

10.6.2 Evidence supporting the big bang theory

Supporters of the big bang theory point to three main pieces of scientific evidence to support their model:

1. There is evidence that the universe is expanding: galaxies are moving further apart, leading scientists to conclude that the galaxies were once closer together before some kind of explosion.
2. It explains the abundance of hydrogen, helium and other elements in the universe.
3. Astronomers have observed the cosmic background radiation throughout the universe, the afterglow of the big bang explosion.

Let us examine this evidence in more detail.



10.6.3 The expanding universe

The Doppler effect

Evidence that the universe is expanding is based on measuring the movement of stars and galaxies away from the Earth using the Doppler effect. Christian Johann Doppler was an Austrian physicist who noted the change in pitch that results from a source of sound approaching or moving away. We often hear the same effect when a high-speed train or aeroplane passes us or when we hear the pitch of a fire-engine's siren change as the fire-engine goes by.

Doppler suggested that this changing pitch in sound waves might be seen in light as well. He predicted that the Doppler effect would produce a change in the frequency of light waves emitted from a moving source. The French physicist Armand Fizeau suggested that this change in frequency might be seen by comparing the spectrum of light from a moving source with that from a stationary one.

As the train approaches, the sound waves reaching you are bunched up. The frequency is higher and you hear a higher pitch.

As the train speeds away, the sound waves reaching you are more spread out. The frequency is lower and you hear a lower pitch.

INVESTIGATION 10.11

The Doppler effect

AIM: To observe the Doppler effect

You will need:

a source of sound that can easily be spun in a circle (e.g. a battery-powered electronic buzzer which produces a single note or a whistle fastened securely in the end of a length of rubber tubing)
a length of strong string
a partner

- Ask your partner to spin the sound source around in a circle on the end of the piece of string. If you are using a whistle, your partner should blow through the attached rubber tubing to produce a sound. Listen carefully to the note produced.

A whistle can be used as a rotating sound source.

CAUTION: Take care while spinning the source. Ensure that the string is strong enough and that no-one is in the path of the rotating source of sound.

Discussion

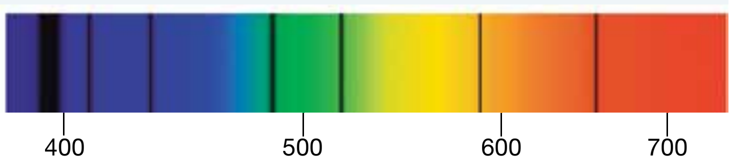
1. What can you hear happening to the pitch of the buzzer?
2. When is the pitch highest? When is it lowest?

10.6.4 The spectra of stars

Stars on the move

When the **spectrum** of the light from a star is analysed, some dark lines are observed. These dark lines correspond to colours of light that have been absorbed by substances in the star. Different substances absorb different colours of light. By identifying the wavelengths of the colours missing from the spectrum, astronomers can find out which elements are present in the star.

The spectrum of white light from a nearby star. The black lines show which colours have been absorbed by elements in the star. The numbers on the scale indicate the wavelength of the light in nanometres. A nanometre is 10^{-9} metre.



In many cases, the black lines, or missing colours, in the spectra of stars are shifted from their expected positions. A shift to lower or 'redder' frequencies is called a **red shift** and results from a star's movement away from the Earth. A shift to higher or 'bluer' frequencies is called a **blue shift** and is caused by a star's movement towards the Earth.

INVESTIGATION 10.12

Observing spectra

AIM: To observe the spectrum produced by a fluorescent light

You will need:

hand-held spectroscope
fluorescent light

- Aim the spectroscope at a fluorescent light in the room.
- Observe the bright spectral lines visible in the spectroscope; at least three should be visible.
- Record the wavelength of each of these lines by reading their position on the scale provided in the spectroscope. Units may not be provided with your scale so for values between 4.0 and 8.0, the wavelength will range from 4.0×10^{-7} to 8.0×10^{-7} metres.

Discussion

1. The spectral lines observed were bright emission lines rather than black absorption lines produced by stars but they still act as a 'fingerprint'. What might this fingerprint indicate about the fluorescent light?
2. If the fluorescent light were moving away from you at fast speed, how would the spectral lines differ to those observed from a stationary fluorescent light?

Retreating galaxies

On a much larger scale, the study of the Doppler shift of galaxies provides us with an amazing picture of the universe. Galaxies within our local group, including the nearby Andromeda Galaxy, are moving slowly towards our own due to gravity. The other, more distant galaxies are moving away from us at a considerable speed. Even more extraordinary is the relationship between the size of the red shift and the distance from Earth. This was first investigated by the astronomer Edwin Hubble and is now referred to as Hubble's law. This law states that the further away a galaxy is, the greater is its red shift and so the faster it is moving away from us.

While this finding appears to put the Earth in a very special position at the centre of a rapidly expanding universe, it is in fact an illusion. Observers anywhere in the universe will see the surrounding galaxies moving away from them at a speed that is consistent with Hubble's law.

10.6.5 Elements in the universe

The amounts of hydrogen and helium in the universe support the big bang theory. According to earlier theories, the only way that helium can be produced is by the nuclear fusion reaction taking place in stars. Almost 10% of the atoms in the universe are helium and the remainder mainly hydrogen. This is far more than could be produced by the stars alone. The percentage of helium atoms can, however, be explained by their synthesis as a result of the big bang.

10.6.6 The afterglow

When George Gamow and Ralph Alpher proposed their version of the 'big bang' theory in 1948, they calculated that the universe now, about 13.7 billion years after creation, would have a temperature of 2.7 °C above **absolute zero**. That's –270 °C. Anything with a temperature above absolute zero emits radiation. The nature of the radiation depends on the temperature. Gamow predicted that, because of its temperature, the universe would be emitting an 'afterglow' of radiation. This afterglow became known as 'cosmic microwave background radiation'.

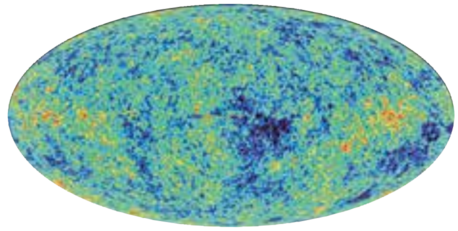
This radiation was discovered by accident in 1965. Engineers trying to track communications satellites picked up a consistent radio noise that they couldn't get rid of. The noise wasn't coming from anywhere on Earth, because it was coming from all directions out in space. In fact, it was the cosmic microwave background radiation predicted by Gamow. Its discovery put an end to the steady state theory, leaving the big bang theory as the only theory supported by evidence currently available. Even Fred Hoyle, who had ridiculed the idea of a 'big bang', admitted that the evidence seemed to favour the big bang theory.

'Mapping' the universe

In 1989, a satellite named COBE (COsmic Background Explorer) was put into orbit around Earth to accurately measure the background radiation and temperature of the universe. COBE could detect variations as small as 0.000 03 °C. As predicted by Gamow, it detected an average temperature of –270 °C.

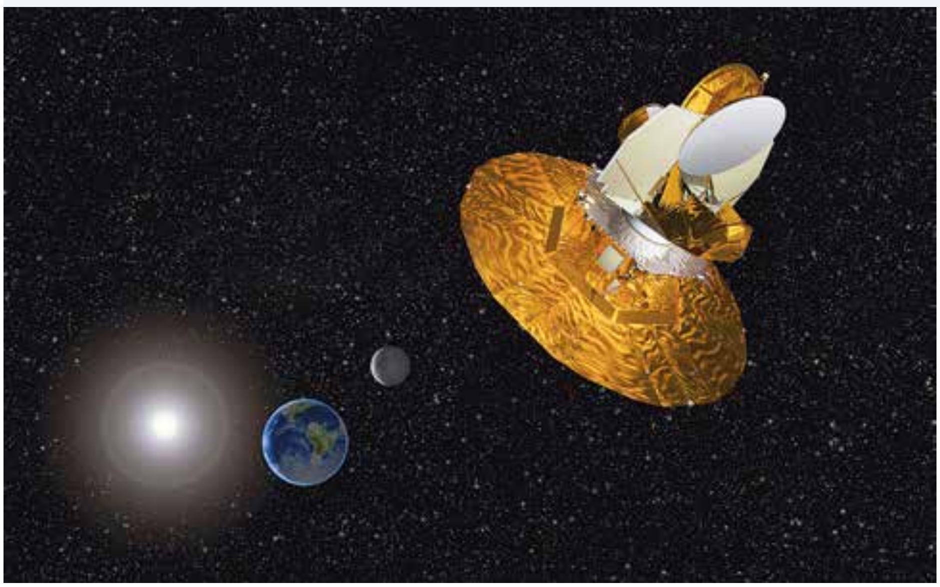
In 2001, a probe called WMAP (Wilkinson Microwave Anisotropy Probe) was sent into orbit around Earth at a much greater distance to gather even more accurate data, detecting temperatures within a millionth of a degree. WMAP's first images were released by NASA in February 2003.

Image of cosmic microwave background radiation taken by the space probe shown below.



The computer-enhanced image of cosmic microwave background radiation shown above was produced by the WMAP mission. The background radiation detected was released only 380 000 years after the big bang — the first radiation to escape. The image shows how the temperature varied across the universe as it was 380 000 years after the big bang. The blue parts of the map are the cooler regions. These regions were cool enough for atoms, and eventually galaxies to form. The red parts are warmer regions. The map shows that galaxies are not evenly spread throughout the universe. They support the theory of an expanding universe that began with a big bang.

The Wilkinson Microwave Anisotropy Probe (WMAP). Its main mission was to gather evidence to help cosmologists find out how the universe began and predict what will happen in the future.



INVESTIGATION 10.13

The expanding universe

AIM: To model the expanding universe

You will need:

a round party balloon
a felt-tip marker

- Draw evenly spaced dots all over the outside surface of the uninflated balloon. The dots should be about 1 cm apart from each other.
- Inflate the balloon by blowing three breaths into it. Hold the opening so air doesn't escape and observe the spacing between the dots.
- Keep inflating the balloon and observe how the spacing between the dots is affected.

CAUTION: **Do not over inflate the balloon!**

Discussion

1. Describe what happened to the distances between the dots as the balloon got bigger.
2. This can be used to model the expansion of the universe. In what ways is this is an accurate model? What aspects of the expansion of the universe are not represented very well?

HOW ABOUT THAT!

The 'big bang' theory would not make any sense at all if it were not for Albert Einstein's famous equation. How could matter be created from 'nothing'? Well, the singularity before the big bang was not 'nothing'. It was a huge amount of energy (with no mass) concentrated into a tiny, tiny point.

Einstein proposed that energy could be changed into matter. His equation $E = mc^2$ describes the change, where:

E represents the amount of energy in joules
m represents the mass in kilograms
c is the speed of light in metres per second (300 000 000 m/s).

Einstein's equation also describes how matter can be changed into energy. That is what happens in nuclear power stations and nuclear weapons.

10.6.7 Steady state or big bang?

Until the early 1900s, astronomers had assumed that the universe was fixed in size. The work of a number of physicists in the early 1900s opened up the possibility of an expanding universe.

In 1915 Einstein formulated his famous general relativity theory that describes the nature of space, time, and gravity. This theory allows for expansion or contraction of the fabric of space. In the 1920s Willem de Sitter and Aleksandr Friedmann independently applied this theory to the entire universe and hypothesised that the universe could be expanding. To account for this expanding universe, Georges Lemaître, a Belgian astrophysicist and Catholic priest imagined all matter initially contained in a tiny universe and then exploding.

Around the same time that the idea of an expanding universe was seriously being considered by the astronomical community, Vesto Slipher collected the first piece of evidence supporting it. He observed the red shift of many spiral galaxies, indicating that they were moving away from us. Further, in 1929 Hubble discovered that galaxies further away were moving away from us at higher speeds. This suggested that the further back in time we go, the smaller the universe was.

In the late 1940s, George Gamow, an American physicist, conceived of the big bang theory as we know it today but it was certainly not universally accepted by physicists. In 1948 Sir Fred Hoyle and others developed an alternative model of the universe that did not start in a massive expansion. Their 'steady state' theory accepted that the universe is expanding but it proposed that matter is continuously created, as it is in stars today, at a rate that keeps the average density of the universe the same as it expands. Interestingly, it was Hoyle who coined the term 'big bang' in an attempt to ridicule the idea that the universe had a beginning. Supporters of steady state theory pointed to the rate of expansion of the universe that had been measured by 1948 which, when calculated backward to an initial big bang, gave an age for the universe of only a few billion years, well below the known age of the solar system. Assuming these calculations were correct, this posed a problem for the proponents of the big bang theory.

In steady state theory the expansion of the universe comes from the continuous creation of the element hydrogen throughout the universe. This hydrogen eventually gathers and condenses into stars. Through nuclear fusion of hydrogen in their cores, stars create all the heavier elements. As stars age, die and explode, they scatter the heavier elements around the galaxies. Consequently, a steady state universe does not change over time even though stars and galaxies are continuously forming within it.

In contrast, the evolutionary model envisaged by Gamow in his big bang theory proposed that the explosion at the birth of the universe created all hydrogen and some helium. These elements formed as the blast expanded and cooled and the first stars were made from this original hydrogen and helium. Those stars fused those original elements into new, heavier elements. These heavier elements were then scattered through the galaxies as the first stars died and led to the more complex mixtures of elements seen in stars now.

Problems with steady state theory began to emerge in the late 1960s, as observations surfaced supporting the idea that the universe was in fact evolving. Quasars were found only at large distances, therefore existing only in the distant past and not in closer galaxies. While the big bang theory predicted as much, steady state theory predicted that such objects would be found everywhere, including close to our own galaxy.

For most cosmologists, rejection of steady state theory came with the discovery in 1965 of the cosmic microwave background radiation, the afterglow of the big bang. Although steady state theory is largely discredited today, proponents of this theory in the 1950s and 1960s did push supporters of the big bang theory to support their theory with scientific evidence.

10.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the science of 'cosmology'.
2. How old is the universe believed to be?
3. According to the big bang theory, **describe** what was there at the time of the big bang.
4. **Recall** approximately how long after the big bang:
   (a) matter appeared
   (b) protons and neutrons formed
   (c) atoms first existed
   (d) galaxies began to form.
5. **Identify** three major pieces of evidence that supported the big bang theory.
6. **Explain** why there are black lines in the spectra of the light emitted by stars.
7. **Recall** which colour of light has the higher frequency — red or blue.
8. **Define** the term 'red shift'. What does it tell us about how a star is moving relative to the Earth?
9. **Explain** what Einstein's famous equation has to do with the big bang theory.
10. **Explain** how steady state theory could accept that the universe was expanding, yet remained the same.
11. **Describe** the evidence that put an end to steady state theory.

Think

12. The light from a star is often analysed by its wavelength instead of its frequency. Long wavelengths correspond to low frequencies and short wavelengths correspond to high frequencies. The spectrum of colours emitted by excited atoms of hydrogen on Earth contains the wavelength 6562.85 angstroms ($1\ \text{Å} = 1 \times 10^{-10}$ m). This same wavelength is observed in the spectrum of light from the bright star Vega at 6562.55 Å. Is Vega moving towards or away from Earth? **Explain** your answer.
13. WMAP is able to provide a picture of the universe as it was 380 000 years after the big bang. **Explain** why it is unable to provide a map of the universe as it was before that time.
14. **Justify** why scientists go to the expense of measuring background radiation with a satellite or space probe when it could be done from Earth.
15. Scientific theories are contested and refined over time by the scientific community. **Explain** why steady state theory was once well accepted by many physicists but it became discredited over time in preference to the big bang theory.
16. Test your understanding of red shift and blue shift by completing the **Shifting spectral lines** interactivity in the Resources tab.

    To find out more about the WMAP mission, including data and images obtained since the publication of this book, use the **WMAP** weblink in the Resources tab. Using the information obtained from the website answer the following questions.
17. What is the average temperature of the universe as measured by WMAP?
18. When were the first stars formed?
19. According to WMAP, how old is the universe, and how accurately is its age known?
20. Enhance your understanding of the model of the universe expanding like a balloon by using the **Expansion of the universe** interactivity in the Resources tab.

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- **Try out this interactivity:** Shifting spectral lines (int-0678)
- **Try out this interactivity:** Expansion of the universe (int-0057)
- **Explore more with this weblink:** WMAP
- **Complete this digital doc:** Worksheet 10.6: The big bang theory (doc-12802)
- **Complete this digital doc:** Worksheet 10.7: The expanding universe (doc-12803)

10.7 Review

10.7.1 Stars and constellations

- **describe** the magnitude scale for comparing the brightness of stars 10.2
- **define** the apparent magnitude of celestial objects and identify the factors influencing it 10.2
- **account for** the apparent motion of stars in the night sky 10.2
- **interpret** a star chart and use it to locate and identify celestial objects 10.2
- relate constellations to the arrangement of stars in the night sky 10.2

10.7.2 The life cycles of stars

- **describe** the formation of stars 10.3
- **interpret** a Hertzsprung–Russell diagram and relate it to the evolution of stars 10.3
- **outline** the nuclear fusion reaction taking place in main sequence stars 10.3
- relate the colour of stars to their size, surface temperature and age 10.3
- **summarise** the stages of stellar evolution for an average sized star and a large star 10.3
- **distinguish** between the terms 'absolute magnitude' and 'apparent magnitude' 10.3

10.7.3 The structure of the universe

- **describe** the Milky Way Galaxy and relate it to the solar system, galaxies in the Local Group and beyond 10.4
- **compare** galaxies and nebulae 10.4
- **describe** efforts to discover exoplanets 10.4
- **identify** that all objects exert a force of gravity on all other objects in the universe
- **describe** differences in sizes of and distances between structures making up the universe 10.4

10.7.4 Astronomical technologies

- **describe** improvements in optical telescopes 10.5
- **account for** the location of ground-based telescopes 10.5
- **account for** the use of telescopes across the entire electromagnetic spectrum and for the need to locate some in space 10.5

10.7.5 Theories on the origins and evolution of the universe

- **define** the term 'spectrum', and explain how it can be used to determine the elements that make up a star 10.6
- **explain** the Doppler effect and describe how it can be used to observe the motion of stars 10.6
- **outline** how the cosmic background radiation and the synthesis of elements in the universe support the big bang theory of the origin of the universe 10.6
- **contrast** the big bang theory and steady state theory of the origin and evolution of the universe 10.6
- **account for** the eventual rejection of steady state theory 10.6

Individual pathways

ACTIVITY 10.1	ACTIVITY 10.2	ACTIVITY 10.3
Revising the universe doc-10667	Investigating the universe doc-10668	Investigating the universe further doc-10669

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FOCUS ACTIVITY

online only

Option 1

Governments are often looking for opportunities to cut funding to scientific institutions involved in pure research such as astronomical observatories. Create a display for an astronomical exhibit that helps to justify the use of public funding to support astronomy. Your exhibit should showcase the use of technology to advance our understanding of the universe. Illustrate the variety of advanced telescopes used to collect information about the diverse celestial objects in the universe.

Option 2

Create an historical exhibit or multimedia presentation to demonstrate how scientific thinking about the origin of the universe is refined over time. Describe the contribution of key physicists in developing our understanding of the origins and evolution of the universe and the evidence used to influence thinking. Research some of the more credible theories on how the universe may end. For example, examine whether physicists think that the universe will continue expanding.
Access more details about focus activities for this topic in the Resources tab (doc-10666).

assessON

10.7 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Give two reasons why a particular star would appear brighter than others in the night sky.
2. **Explain** why stars appear to twinkle.
3. Why do the positions of stars change over the course of a night's viewing?
4. The stars in a constellation are located close to each other. Do you agree? **Explain**.
5. (a) How old is the sun?
   (b) How long before it reaches the end of its life?
   (c) What will the sun become after it leaves the main sequence?
6. Draw a flow chart to outline the life cycle of a large star.
7. **Outline** how the colour of a star depends on its temperature.
8. **Distinguish** between the apparent magnitude of a star and its absolute magnitude.
9. **Contrast** a nebula and a planetary nebula.
10. (a) How are galaxies classified?
    (b) In what category does the Milky Way Galaxy belong?
11. Where is the solar system located in the Milky Way?
12. Exoplanets, or planets beyond the solar system, are generally too small to be seen by direct observation. **Describe** how these planets are discovered.
13. Why do galaxies throughout the universe appear to be clumped, rather than evenly distributed?
14. **Outline** how optical telescopes can be designed and located to maximise the clarity of the images seen.
15. **Explain** why it is important for astronomy to utilise telescopes that detect a range of frequencies across the electromagnetic spectrum, not just visible light.
16. **Explain** why only optical telescopes and radio telescopes can be located on the ground.
17. New generations of space telescopes can see further and further into the universe. **Explain** why this allows astronomers to view the universe early in its evolution.

18. **Describe** the big bang theory.
19. The visible light spectrum emitted by stars can be analysed with an instrument called a spectroscope.
    (a) **Explain** why the visible light spectrum from stars has some black lines in it.
    (b) When the visible spectrum of a glowing fluorescent light tube is viewed on Earth, **Describe** what information about the tube can be obtained from the positions of the bright lines.
    (c) What happens to the black lines in the spectrum of a star if there is a red shift?
    (d) What does a red shift in the spectrum of a star tell us about the star?
20. (a) What is the cosmic background radiation?
    (b) How does it provide evidence of the big bang?
21. Steady state theory was accepted by many physicists prior to 1965.
    (a) **Contrast** the steady state and big bang theories.
    (b) **Explain** why steady state theory lost favour with many physicists after 1965.

Test yourself

1. A galaxy is defined as:
   (A) a glowing cloud of gas and dust.
   (B) a region of star formation.
   (C) a concentration of stars, gravitationally linked.
   (D) a ring of expanding gas. **(1 mark)**
2. **Identify** which of the following sequences best describes the life cycle of a medium sized star.
   (A) Red giant, main sequence star, protostar, supernova
   (B) Main sequence star, red giant, supernova, protostar
   (C) Protostar, red giant, main sequence star, black hole
   (D) Protostar, main sequence star, red giant, supernova **(1 mark)**
3. Which of the following theories accounts for how the universe began?
   (A) The big bang theory
   (B) The Doppler effect
   (C) General relativity
   (D) Hubble's law **(1 mark)**
4. Stars that are red shifted:
   (A) are becoming redder.
   (B) are moving away from the solar system.
   (C) have more spectral lines in the red region of the visible spectrum.
   (D) have depleted the hydrogen in their core. **(1 mark)**
5. Use the big bang theory to account for how the universe originated and has evolved over time. **Describe** the evidence used to support this theory. **(6 marks)**

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Complete this digital doc: Worksheet 10.8: The mysterious universe puzzles (doc-12804)

Complete this digital doc: Worksheet 10.9: The mysterious universe summary (doc-12805)

TOPIC 11 Genetics

11.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

11.1.1 Why learn this?

Features such as hair colour, freckles and susceptibility to certain diseases tend to run in families. We inherit these features from our parents. Have you ever wondered how characteristics are passed on from one generation to the next? The DNA in our cells carries the information that makes us who we are. This DNA originally came from an egg and a sperm produced by your parents. In this topic you will learn about DNA and how characteristics are inherited. You will also learn about some recent biotechnological advances and their implication to society.

DNA: the blueprint of life

LEARNING SEQUENCE

Thinking about characteristics

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. At right and on the next page are some pictures of celebrities and their children.
   (a) Can you match each celebrity with their child? Answers are provided below the questions.
   (b) Which features were most useful to help you match up the pictures?
   (c) Characteristics that are passed from parent to child are said to be inherited. Apart from features that relate to physical appearance, what other features are inherited?
   (d) Characteristics are passed from both parents. List some features you have inherited from your mother and some you have inherited from your father.
2. Below are some statements about heredity. Which of the statements are myths and which are facts?
   (a) It is impossible for two brown-eyed parents to have a child with blue eyes.
   (b) Your weight is determined by your genetic make-up to some extent.
   (c) A woman who eats a high protein diet during the first 2 months of pregnancy is more likely to give birth to a son.
   (d) It is possible for a person to carry a gene for a genetic disorder and not know it.
   (e) Some types of cancers are hereditary.
   (f) Identical twins are natural clones.
   (g) In the majority of cases, genetic disorders are due to a problem with the mother's egg cells rather than the father's sperm cells.
   (h) A brother and sister who are twins have exactly the same DNA.

A4, B6, C7, D5, E3, F2, G1

Parent A

Child 1

Parent B

Child 2

Parent C

Child 3

Parent D

Child 4

Parent E

Child 5

Parent F

Child 6

Parent G

Child 7

11.2 It's in the genes

11.2.1 Genes and chromosomes

Do you have freckles? Can you roll your tongue? Is your hair naturally curly or straight? These features and many others are determined by your genes, which are inherited from your parents.

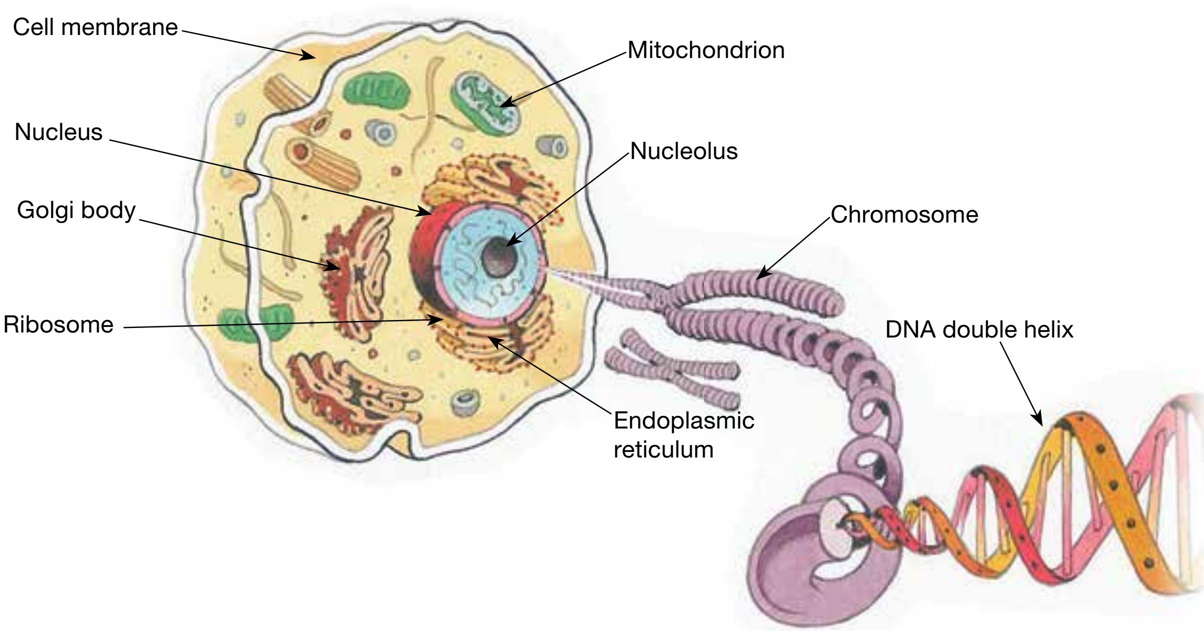
Look at the people around you — everyone has unique characteristics or **traits**. Many of your traits are determined by your **genes**. A gene is a piece of **DNA (deoxyribonucleic acid)**. DNA is a chemical found in the nucleus of cells. Each gene contains the instructions for constructing a particular polypeptide. Proteins containing one or more polypeptides can then be formed, and your characteristics determined by the proteins the DNA codes for. For example, the gene called F8 contains the instructions for making a protein called factor VIII, found in blood. It helps blood to clot when you cut or bruise yourself. If the F8 gene is faulty no factor VIII is made. People who have haemophilia A have a faulty F8 gene so that their blood does not clot normally following an injury.

Genes control characteristics.

Genes determine many of your physical characteristics including eye colour, the shape of your ears and nose, and your natural hair colour. They also play a part in determining your personality and behaviour. Numerous diseases including some cases of breast cancer, colour blindness and cystic fibrosis have a strong genetic component.

DNA is found in the nucleus of cells. Most of the time the DNA is in the form of long thin strands and cannot be seen with a light microscope. However, when a cell is about to divide, the DNA strands coil up and form into **chromosomes**. The chromosomes can then be seen using a light microscope if they are stained with a dye such as methylene blue. Chromosomes are made up of DNA and other substances, including proteins.

DNA is found in the nucleus of cells. Prior to cell division it coils up into structures that, when stained, can be seen with a microscope. These structures are called chromosomes.



Most of the cells of healthy humans contain 23 matching pairs of chromosomes. Exceptions are gametes (egg and sperm cells). These contain only 23 chromosomes. Red blood cells do not contain a nucleus, so they do not have any chromosomes.

A **karyotype** is a picture showing the chromosomes organised in matching pairs in order of size from biggest to smallest. In some karyotypes the chromosomes look like rods with a thinner section (the centromere), and sometimes they look X shaped. The chromosomes that are X shaped actually consist of two identical parts (chromatids) that are attached together at the centromere. Later in the cell division process the chromatids will separate and look like rods.

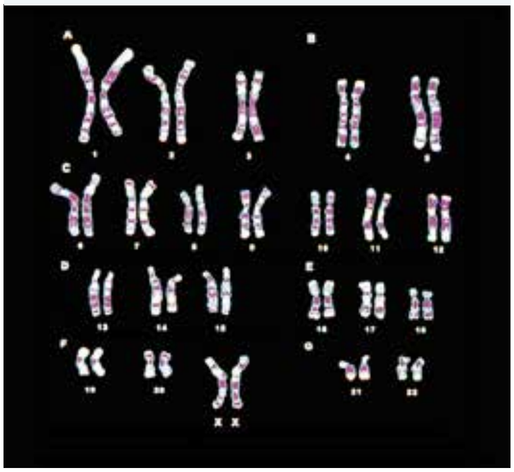
The karyotype of males and females looks different. In females, a pair of chromosomes, referred to as the sex chromosomes, are identical. In males, however, one of the sex chromosomes is smaller than the other, so that instead of looking X shaped when the chromatids are attached together, it looks Y shaped. For this reason females are said to have two X sex chromosomes and males have an X and a Y sex chromosome.

Karyotyping may reveal certain genetic disorders where cells do not have the usual 46 chromosomes, such as Down syndrome or Turner syndrome. People who have Down syndrome have 47 rather than 46 chromosomes in their cells. In most cases all cells are affected but in a small number of cases only some of the cells have 47 chromosomes. The symptoms of Down syndrome vary greatly but may include delay in physical, intellectual and language development, heart defects (in 30–50% of cases), abnormalities of the digestive tract (in 8–12% of cases) as well as particular physical features.

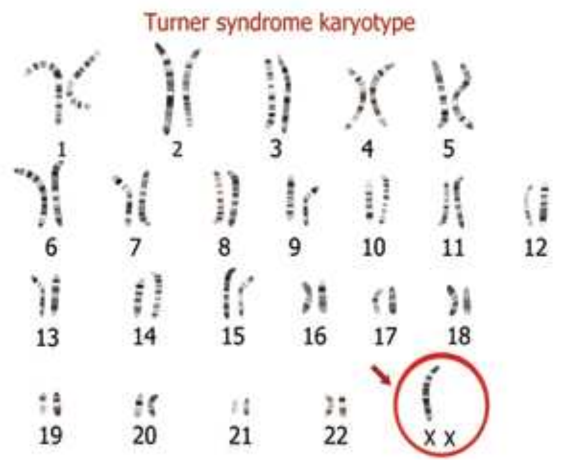
In Turner syndrome the karyotype reveals that there are only 45 chromosomes. Instead of two sex chromosomes there is only one X chromosome. A person who has Turner syndrome is female but her reproductive system may not function properly. She is likely to be short and have other physical characteristics including a low hairline, low-set ears and a webbed neck. She may also have problems with her heart, eyes, ears and thyroid gland and may have learning difficulties, although symptoms vary greatly.

A child who has Down syndrome

A human karyotype



Karyotyped chromosomes of a girl with Turner syndrome



HOW ABOUT THAT!

The humble platypus has 10 sex chromosomes

The platypus is a rather strange animal and the more scientists find out about it, the weirder it turns out to be. In 2004 a team of researchers from the Australian National University in Canberra worked out that the platypus has 26 pairs of chromosomes and of these, 5 pairs are sex chromosomes.

The number of chromosomes varies between species. Human body cells usually have 46 chromosomes. There does not seem to be a link between the number of chromosomes and the animal's complexity. Fruit flies have only 8 chromosomes, kangaroos have 12 and shrimp have an astounding 254 chromosomes!

11.2 Exercise: Remember and think

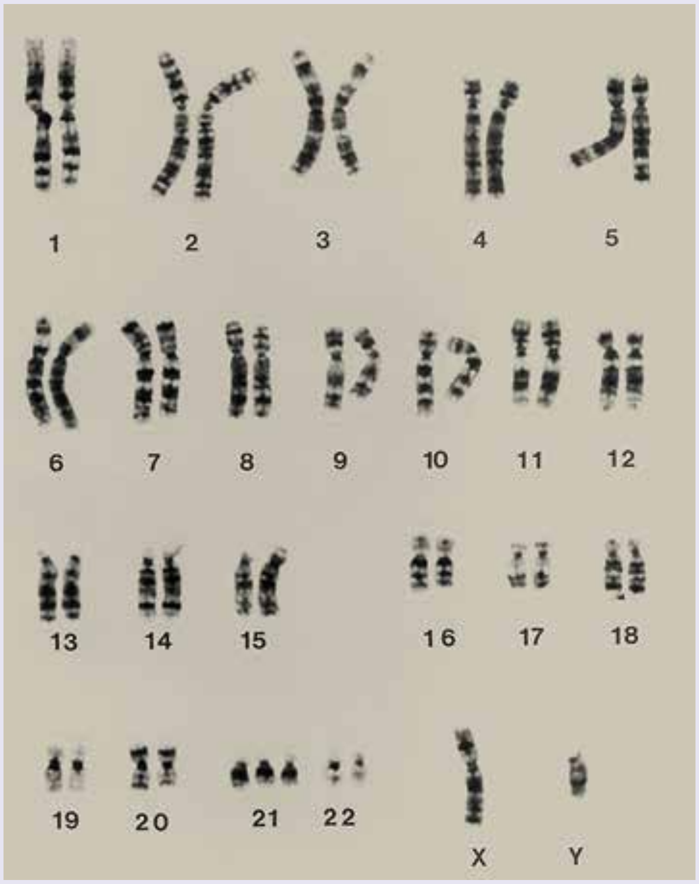
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** what genes are made of and where they are found.
2. How many pairs of chromosomes do most human cells contain?
3. Write the following in order from largest to smallest:
   gene, cell, nucleus, chromosome, organism.
4. Are chromosomes always visible in a cell? **Explain**.
5. **Describe** what a karyotype is and why it is important.

Think

6. If each cell nucleus has about one metre of DNA, how does the DNA fit inside the cell?
7. A karyotype for a child with Down syndrome is shown below.
   (a) Compare this karyotype to the normal human karyotype.
   (b) Deduce whether the child is male or female. **Justify** your answer.
   (c) Down syndrome is sometimes called Trisomy 21. **Explain** why. You may need to look up the word 'trisomy' in a dictionary.



Skill builder

8. The table below shows the number of chromosomes in body cells of some organisms:

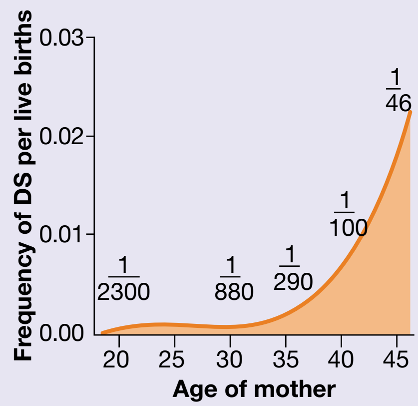
Number of chromosomes in body cells (non-sex cells) of some living things

Species of living thing	Number of chromosomes in each body cell
Chimpanzee	48
Euglena (unicellular organism)	90
Fruit fly	8
Human	46
Koala	16
Onion	16
Shrimp	254

Species of living thing	Number of chromosomes in each body cell
Sugar cane	80
Tomato	24
Cabbage	18
Frog	26
Housefly	12
Pig	40
Platypus	52
Rice	24
Sheep	54

(a) **Construct** a column graph for the data in the table above.
(b) **Identify** which species' body cells have:
(i) the highest total number of chromosomes
(ii) the smallest total number of chromosomes.
(c) Do you think that the number of chromosomes reflects the intelligence of an organism? **Justify** your answer.

9. The graph below right shows the relationship between the age of the mother and the incidence of Down syndrome.
(a) A 30 year old woman is pregnant. What is the probability that the child she is carrying has Down syndrome?
(b) If the woman was 45 instead of 30, what would be the probability that her child had Down syndrome?
(c) CVS testing and amniocentesis can detect Down syndrome before 20 weeks of pregnancy. Couples who find out their child has Down syndrome or another serious chromosomal abnormality may decide to terminate the pregnancy (have an abortion).
(i) **Discuss** whether you would choose to have these tests done if you (or your partner) were pregnant and older than 35.
(ii) Older pregnant women are more likely to be offered CVS testing or amniocentesis. **Explain** how this could eventually change the shape of the graph at right.



Investigate

10. Locate information about conditions other than Down syndrome and Turner syndrome where the number of chromosomes is not 46. **Summarise** the information in a table with the following headings: 'Name of condition', 'Description of karyotype' and 'Characteristics'.
11. Use the **Karyotype** weblink in the Resources tab. Follow the instructions provided to prepare and interpret karyotypes for some patients.
12. Use the **University of Utah** weblink in the Resources tab to learn more about the basic terminology relating to genetics.

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Explore more with this weblink: Karyotype

Explore more with this weblink: University of Utah

Complete this digital doc: Worksheet 11.1: Genes and chromosomes (doc-12806)

11.3 Cell division

11.3.1 Mitosis

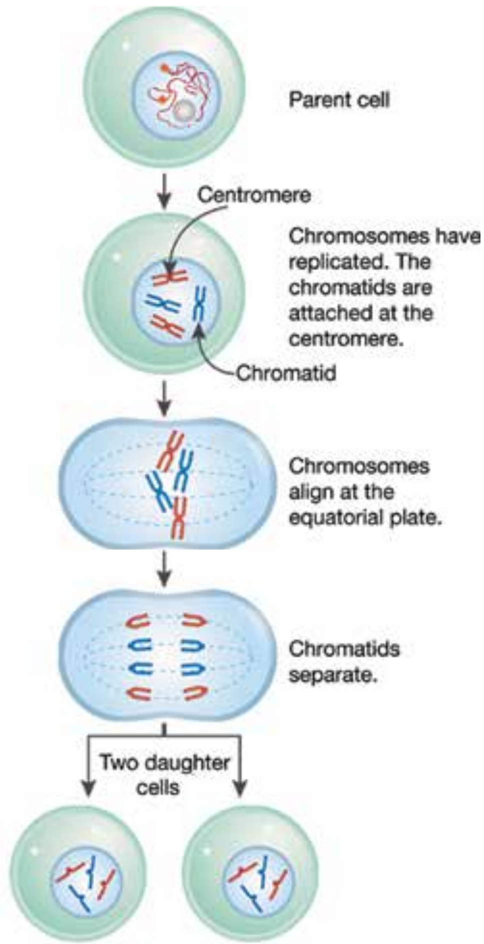
Organisms need to make new cells all the time. Cells are needed for growth and development, to replace dead cells and to repair tissues. The new cells are made by cell division. Cell division also plays an important role in reproduction. Organisms that are made up of only one cell, including bacteria, reproduce by simply dividing in two. In species that reproduce sexually, a different type of cell division produces the egg and sperm cells that are needed to create a new life. Understanding this type of cell division can help explain how we inherit certain features from our parents.

Mitosis is a type of cell division that produces daughter cells with the same number and type of chromosomes as the parent cell. It produces the new cells needed for growth and the repair of tissues. In plants, mitosis occurs only in certain parts of the plant, including the tips of the roots and stems. If you look at a section of a root tip under the microscope you may be able to see cells at various stages of mitosis. Mitosis is the process that turns a single fertilised egg into the trillions of cells that make up an adult human. Every time you dry your skin with a towel some of your skin cells are left on the towel. Mitotic cell division produces the new skin cells needed to replace these.

The diagram at right shows the process of mitosis. The diagram refers to the **diploid** number. This is the number of chromosomes found in most body cells except gametes (egg and sperm cells). In most body cells chromosomes occur in pairs. Gametes contain only half the number of chromosomes of other body cells. This is the haploid number.

After mitosis has occurred the cell membrane pinches in so that the cell divides in two. This process is known as cytokinesis.

Mitosis



Each daughter cell contains the diploid ($2n = 4$) number of chromosomes.

HOW ABOUT THAT!

Our first female Nobel Prize recipient!

In 2009 Dr Elizabeth Blackburn became the first Australian woman to be awarded a Nobel Prize. Together with two colleagues she discovered an important enzyme called telomerase. In the 1970s Dr Blackburn had discovered that at the end of chromosomes there is a cap of DNA. These are the telomeres. Dr Blackburn compares these to the bits of plastic at the ends of shoe laces that stop the shoe laces from fraying. The telomeres are essential for normal cell division, but each time the chromosomes replicate the telomeres become shorter, until eventually they become too short. The cell stops dividing and dies.

Telomerase is an enzyme that maintains and repairs the telomeres. Other scientists have shown that mice that are genetically engineered to lack telomerase age prematurely. When the enzyme was replaced the mice bounced back to health. There are hopes that telomerase may one day be useful in the treatment of diseases linked to the ageing process, although we are a long way off using telomerase as a fountain of youth. Any drug that prevents cell death after a certain number of divisions has the potential to cause cancer.

Dr Elizabeth Blackburn

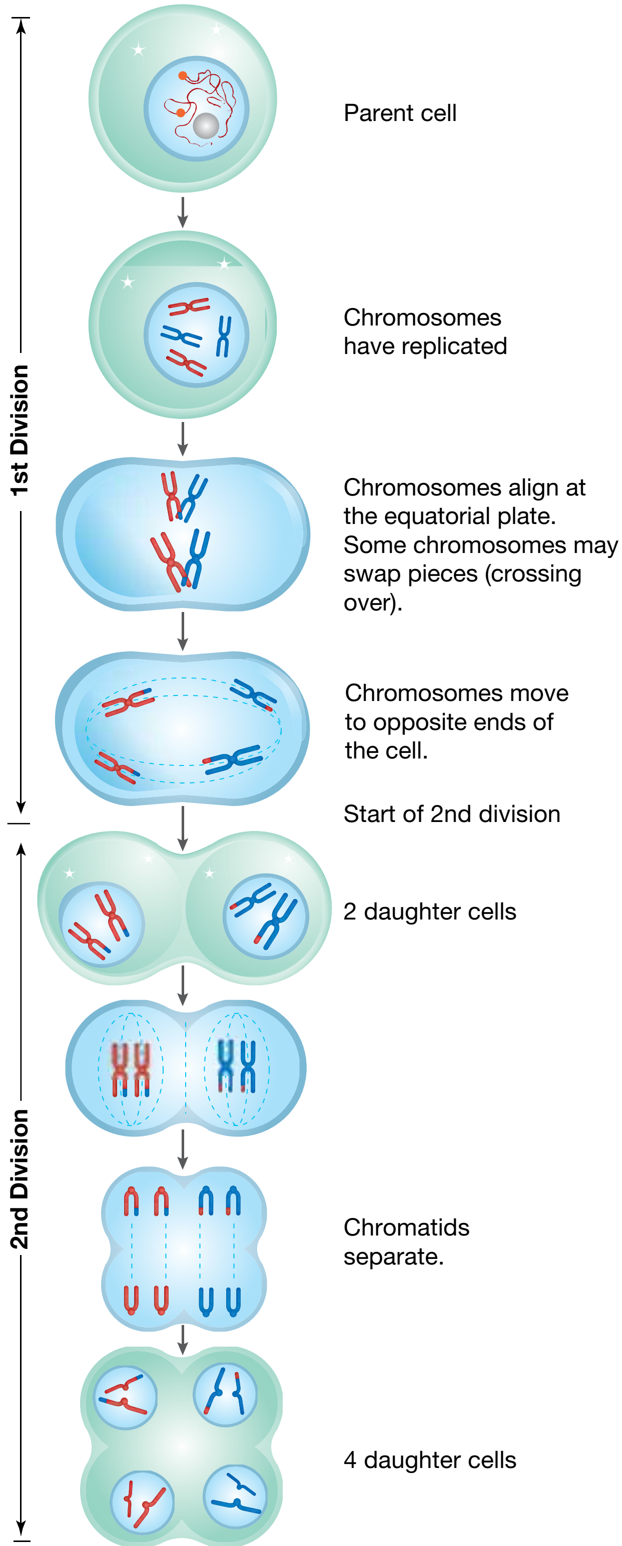
11.3.2 Meiosis

Meiosis is a type of cell division that produces daughter cells with half the number of chromosomes of the parent cell. It produces gametes. In gametes the chromosomes are not in pairs. The diagram below right shows the process of meiosis.

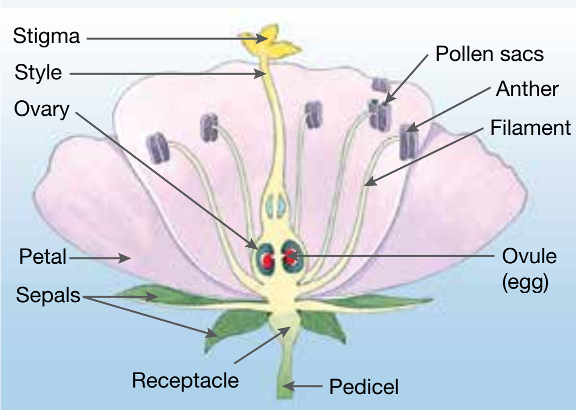
In humans, meiosis occurs in the ovaries for females and in the testes for males. It produces the egg and sperm cells. In flowering plants, meiosis produces the male sex cells that are found inside pollen grains and the female sex cells that are inside the ovules in the ovary of the flower (see the figure below left).

When meiosis occurs, it is pure chance how the chromosomes will be divided between the gametes. In the first half of meiosis chromosomes line up in the middle of the cell in matching pairs (homologous pairs). In each homologous pair one chromosome was inherited from the mother (maternal chromosome) and the other was inherited from the father (paternal chromosome). When the homologous pairs separate, chance determines which cell will end up with the maternal and paternal chromosome from each pair. Since humans have 23 pairs of chromosomes, there are 2^{23} or 8 388 608 different ways that the chromosomes can be divided. That means that a man can produce 8 388 608 different types of sperm cells and a woman can produce 8 388 608 types of egg cells (although she will never actually produce that many!). That number is further increased by the fact that chromosomes can swap sections when they are in homologous pairs. This introduces a further source of variation.

Meiosis



The male sex cells are inside the pollen grains on the anthers and the female sex cells are in the ovules.



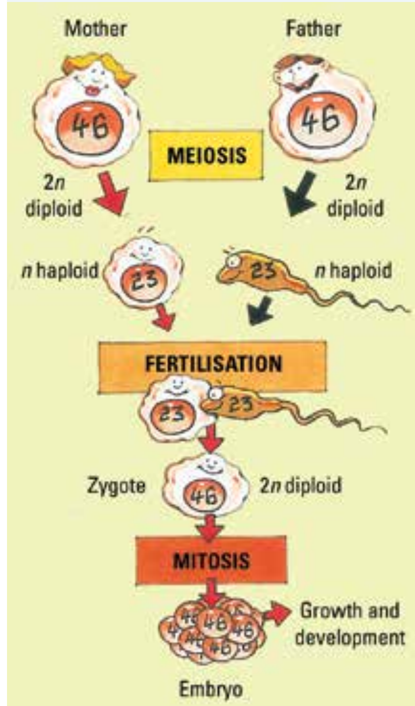
11.3.3 Fertilisation

At fertilisation a male and a female gamete combine, so the fertilised egg (a zygote) has a diploid number of chromosomes. Half the chromosomes in the zygote come from the sperm cell that fertilised the egg — the paternal chromosomes. The other half were in the nucleus of the egg cell — the maternal chromosomes. The chromosomes in the zygote will then be copied each time mitosis occurs, so that all the body cells will end up with a copy of the chromosomes that were present in the zygote. That means that in each of the cells in your body you have 23 chromosomes you inherited from your dad and 23 from your mum. For each characteristic that is genetically determined you have two bits of DNA that code for the polypeptide that contributes to that characteristic: one from your mum and one from your dad.

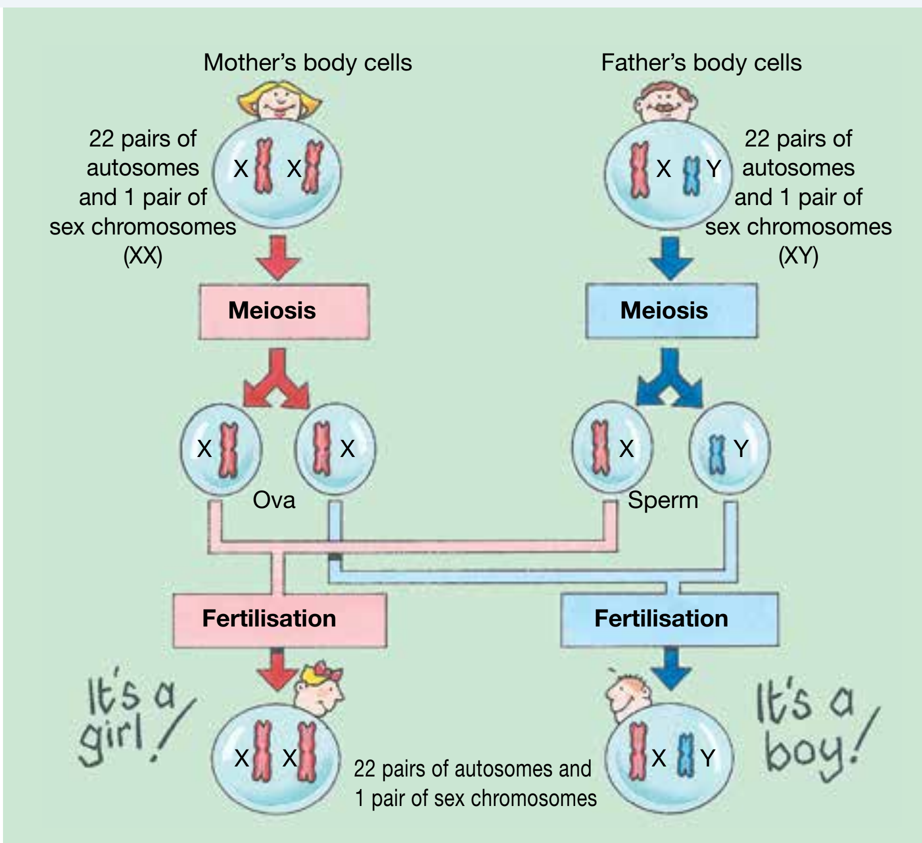
11.3.4 Girl or boy?

The cells of women have two X chromosomes, so in the ovaries, meiosis produces egg cells with one X chromosome. The cells of men however, contain one X and one Y chromosome, so when meiosis occurs in the testes some of the sperm cells contain an X chromosome and others contain a Y chromosome. The sex of a baby is determined by the type of sperm cell that fertilises the egg. An egg fertilised by a sperm containing an X chromosome results in a baby girl. If the sperm contains a Y chromosome a baby boy is produced.

You are a product of both meiosis and mitosis.



Sex determination in humans



INVESTIGATION 11.1

Modelling mitosis and meiosis

AIM: To create a model and meiosis

You will need:

paper or cardboard
markers
pipe cleaners of 2 colours
digital camera or phone

- Using the diagrams on the previous pages and the animations in your Resources tab as a guide, model the process of mitosis in a cell containing 2 pairs of chromosomes.
  - The pipe cleaners represent chromosomes. Use one colour for the maternal chromosomes and the other colour for the paternal chromosomes.
  - Draw the cell membrane and any other important detail on the paper or cardboard.
- Take a photo of each step involved, then organise your photos into a flowchart with captions for each step.
- Repeat the same procedure to create a model of meiosis.

Discussion

1. What are the advantages of using models such as these in Science?
2. What were some of the limitations of your model (are there things you could not show clearly; was your model misleading in any way)?
3. Some animations of mitosis and meiosis are available from the weblinks in your Resources tab. What are the advantages of using animations rather than static models to demonstrate the processes involved in cell division?

11.3.5 Sex selection

There are thousands of folk legends about how to select the sex of a child: for a boy, eat meat, salty food, and drink cola; for a girl, stick to fish, vegetables and sweets. These legends are not supported by scientific evidence. In fact, once a human ovum has been fertilised the sex of the baby is determined. The mother's diet during pregnancy has no effect at all on the sex of the baby.

There are instances where sex selection may be important for medical reasons. If the mother is a carrier for a sex-linked genetic disorder a couple may wish to avoid giving birth to a baby boy, for example.

Today it is possible to sort sperm containing X chromosomes from those containing Y chromosomes, although not with 100 per cent accuracy. Combining this with artificial insemination or IVF techniques, couples can increase the chances of having a child of the sex of their choice. Using this technology to decrease the chance of producing a child with a serious genetic disorder raises ethical issues. Even more controversial is the use of the technology to increase the chance of producing a child of a particular sex for no medical reason.

Boy or girl? Should parents have the right to choose?

For some Australian couples the desire for a baby of a particular gender is so strong that they are willing to pay large amounts of money to have IVF treatment overseas. In the US it is legal to use IVF for sex selection. Eggs from the mother and sperm from the father are combined in a dish. Embryos are produced and then tested to find out if the embryos are male or female. If the couple prefers to have a girl, one or more female embryos is implanted. The use of IVF for sex selection is banned in Australia. Should it be legal?

HOW ABOUT THAT!

The sex of reptiles

In some reptiles sex is not determined by chromosomes, but by the environment surrounding the egg. For many reptiles, the main factor determining sex is the temperature of the egg at a critical period during development. In one species of Australian lizard *(Bassiana duperreyi)* chromosomal sex determination occurs, but it can be overridden by temperature and egg size!

Temperature control of sex in some reptiles

Reptile	Cold 20–27 °C	Warm 28–29 °C	Hot > 30 °C
Turtle	Male	Male or female	Female
Crocodile	Female	Male	Female
Lizard	Female	Male or female	Male

11.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Copy and complete the following paragraphs using the words from the list below.
   four; half; haploid; same; two
   During mitosis one parent cell gives rise to __________ daughter cells that have the __________ number of chromosomes as the parent cell.
   During meiosis, one parent cell gives rise to __________ daughter cells that have __________ the number of chromosomes compared to the parent cell. The daughter cells are __________ , not diploid.
2. Copy and complete the following sentences using words from the list below.
   23; 23; 46; embryo; females; ovum; parents; sperm; zygote.
   (a) ________ produces gamete (ova) containing _______ chromosomes.
   (b) Males produce gametes (_________ cells) containing _________ chromosomes.
   (c) One sperm fertilises an _______ to form a _________ with _________ chromosomes.
   (d) The _______ grows and develops into a new individual with traits from both ________.
3. Match each of the terms below with its definition.

Terms	Definitions
(a) Gametes	(i) The number of chromosomes in normal body cells
(b) Haploid number	(ii) A type of cell division that produces cells with half the number of chromosomes of the parent cell
(c) Diploid number	(iii) Sex cells
(d) Fertilisation	(iv) A type of cell division that produces cells with the same number and type of chromosomes as the parent cell
(e) Mitosis	(v) The number of chromosomes in gametes
(f) Meiosis	(vi) When a female and male sex cell combine

4. **Outline** why cell division takes place.
5. What are telomeres?
6. **Explain** why researchers are interested in finding out more about telomerase.

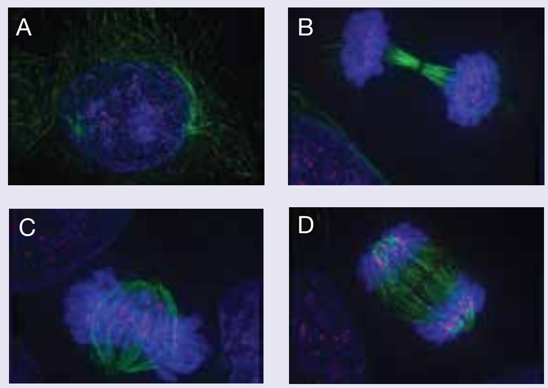
7. **Compare** and contrast mitosis and meiosis using the following table.

	Mitosis	Meiosis
Number of daughter cells produced		
Number of chromosomes in daughter cells compared with parent cell		
For growth and development? Yes/No		
For reproduction? Yes/No		

Think

8. **Explain** why gametes need to have half the number of chromosomes of normal body cells.
9. Use labelled diagrams, or a series of diagrams to **distinguish** between:
   (a) chromosomes and chromatids
   (b) maternal and paternal chromosomes
   (c) fruit fly gametes and fruit fly somatic cells.
10. The diagrams at right show bluebell cells at various stages of mitosis. If picture A is the first stage, put the other pictures in the correct order.
11. **Explain** why a woman's diet during pregnancy cannot possibly affect the sex of her baby.
12. ICSI is a type of reproductive technology where a sperm cell is inserted into an egg cell outside the body to produce a zygote. The zygote goes through a number of cell divisions outside the body, then is inserted into the uterus where it will hopefully implant and develop into a baby.
    At a fertility clinic a technician found that when carrying out this procedure she tended to produce more male babies than the other technicians. When she was observed it was noted that she tended to select sperm cells that were floating higher up in the semen sample whereas the other technicians were more random.
    (a) **Explain** why the sperm cell, rather than the egg cell determines the sex of the baby.
    (b) The Y sex chromosome is smaller than the X sex chromosome. Suggest why selecting sperm cells floating higher up in the semen sample might be more likely to produce male babies.

Mitosis in bluebell cells. What is the sequence of stages shown?



13. **Discuss** whether a couple should be allowed to choose the sex of their baby.
14. **Deduce** the impact of global warming on the ratio of male to female turtles. How might this impact on the survival of turtle species?
15. Use the **Mitosis and meiosis** interactivity in the Resources tab to test your knowledge of different processes of cell division, and challenge yourself to see if you can differentiate between them.
16. To find out more about cell division use the **Mitosis** and the **Meiosis** weblinks in the Resources tab.

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Try out this interactivity: Mitosis and meiosis (int-0680)
Explore more with this weblink: Mitosis
Explore more with this weblink: Meiosis
Complete this digital doc: Worksheet 11.2: Mitosis (doc-12807)
Complete this digital doc: Worksheet 11.3: Meiosis (doc-12808)

11.4 It all started with peas

11.4.1 The start of an idea

It is not uncommon today for couples to visit a genetic counsellor so they can find out the chance of giving birth to a child with a particular genetic disorder. Our understanding of the patterns of inheritance of genetic disorders and other characteristics started with experiments involving peas. These experiments were carried out by Gregor Mendel, an Austrian monk, about 150 years ago. The findings made by Mendel have since been built on by other researchers. Today's leading edge genetics research had very humble beginnings.

Mendel was the first person to suggest how individual traits were inherited. He grew peas and had the idea of looking at just one trait at a time; for example, whether the pea plant had green pods or yellow pods. **Mendelian genetics** is the analysis of the inheritance of a trait that is controlled by a single gene. His model allowed accurate prediction of the features of the offspring of a particular cross.

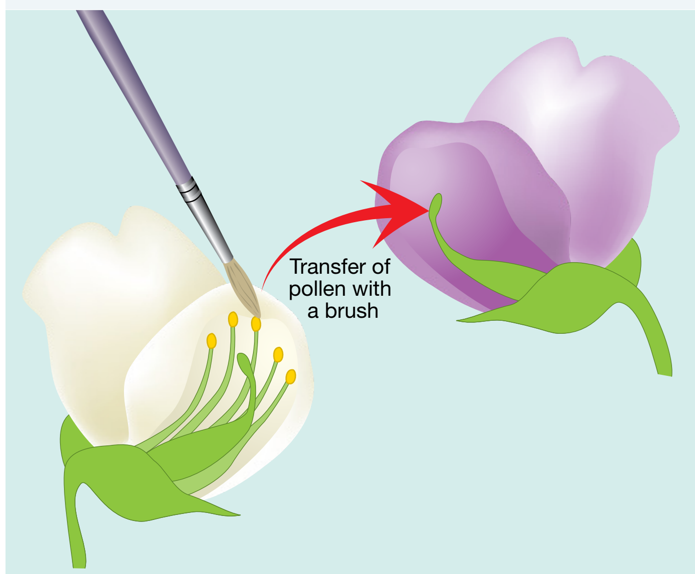
Gregor Mendel

Mendel's experiments with peas were well designed for a number of reasons:

- He used peas. This was a good choice because peas grow quickly and many generations of pea plants can be grown in a relatively short time. Imagine if he had used elephants instead of peas! He would have been waiting a very long time for the next generation.
- He controlled which plants were crossed. The diagram below right shows how Mendel did this.
- He used a very large number of plants.
- The pea plants he started with were pure breeding — he used plants that were descendants of plants that had shown the characteristic he was interested in for many generations. A pure breeding purple flowered plant is the descendant of a long line of purple flowered plants, for example.

Mendel did his breeding experiments at a time when computers and calculators were not available. He recorded his observations meticulously by hand. More importantly he used mathematics to analyse his results. When he processed his results he discovered some interesting patterns. For example he found that when pure breeding tall plants were crossed with pure breeding short plants all the plants produced (the F_1 generation) were tall. When the plants in the F_1 generation were crossed though, $\frac{1}{4}$ of the plants produced (the F^2 generation) were short and $\frac{3}{4}$ were tall.

Mendel transferred pollen from the stamen of a white flower to the pistil of a violet flower.

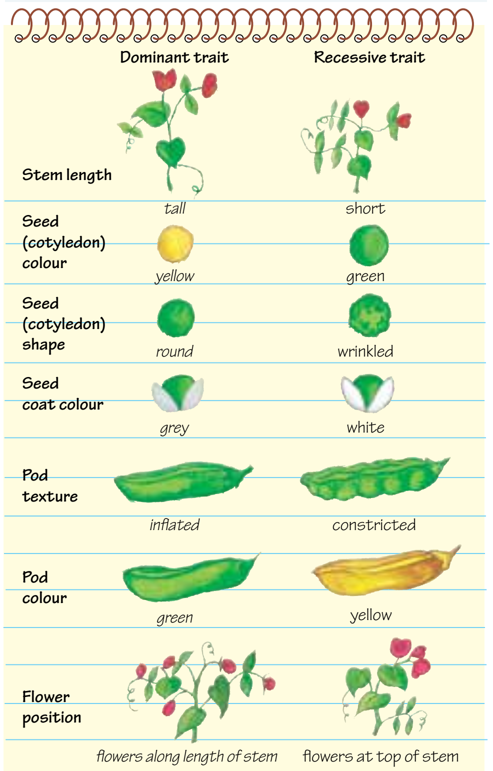


The diagram at right shows some of the characteristics Mendel studied. He found similar patterns in the data he collected for all the characteristics he studied.

Gregor Mendel published his findings in a German journal rather than in one of the more widely read English journals. Mendel was not known within the scientific community of the time and the concepts he presented were too complex for many people to understand, so the ideas he presented were not initially accepted. It was not until after he had died that his work was rediscovered and its significance understood. His original paper was translated into English and his experiments were repeated.

In the days of Mendel DNA and genes had not yet been discovered, but he understood that something must be passed on from one generation to the next for characteristics to be inherited. He called these factors. He proposed that each parent passed on half its factors to each offspring and that certain factors were dominant over others.

The characteristics Mendel investigated in his experiments



11.4.2 Modern day terminology

We now know that what we inherit from each parent are chromosomes containing genes. There are different versions of genes; these are called alleles. So in pea plants tall and short are two alleles for a particular gene. Since each of our cells contains 23 pairs of matching chromosomes, we have two sets of DNA instructions for each characteristic. For some characteristics the DNA instructions are the same. We have inherited the same allele from each parent. For other characteristics we have inherited a different set of instructions (a different allele) from each parent. By pure chance, all the characteristics that Mendel investigated were of the type where one allele is dominant and the other is recessive. The dominant allele masks the effect of the recessive allele. A pea plant that has a copy of the yellow seed allele (dominant) and the green seed allele (recessive) produces yellow seeds. This is the case for many human characteristics as well. In some instances two different alleles produce a blending effect, or both alleles might be expressed. White carnations crossed with red carnations produce pink carnations.

Two terms that are now frequently used when talking about inheritance are homozygous and heterozygous. Mendel used true breeding plants in his experiments. We now know that these plants had two copies of the same allele for the characteristic he was studying. Homozygous is a term used to describe organisms that have two copies of the same allele whereas heterozygous organisms have inherited a different allele from each parent.

The genotype of an organism shows the alleles of an organism for a particular characteristic. The genotype RR tells us a pea plant has two copies of the allele for round seeds whereas Rr indicates it has a copy of the allele for round seeds and a copy of the allele for smooth seeds. The phenotype of an organism describes the actual characteristic. Plants with the genotypes RR and Rr have the same phenotype — they have round seeds.

From Mendel to punnett squares

Reginald Punnett was a supporter of Mendel's ideas. He designed a special type of diagram called a punnett square that is still used today to predict the outcome of a genetic cross. Some conventions (rules) apply when drawing a punnett square:

- A capital letter is used to represent the allele for the dominant trait (e.g. *T for tall*).
- The same letter (but lower case) is used to represent the allele for the recessive trait (e.g. *t for short*).
- If neither allele is dominant, different letters are used to represent them and upper case is usually used. Examples of punnett squares are shown below.

Punnett square 1: cross between a pure breeding tall plant and a pure breeding short plant. All offspring will have the genotype *Tt* and the phenotype tall.

TT × *tt*

	T	T
t	Tt	Tt
t	Tt	Tt

Punnett square 2: the heterozygous tall plants from the previous punnett square are crossed. $\frac{1}{4}$ of offspring will have genotype *TT*, $\frac{1}{4}$ will be tt and $\frac{1}{2}$ will be *Tt*. In terms of phenotype $\frac{3}{4}$ of the plants will be tall and $\frac{1}{4}$ short.

Tt × *Tt*

	T	t
T	TT	Tt
t	Tt	tt

The short pea plant on the right has the genotype *tt*. The tall plant on the left may be *TT* (homozygote) or *Tt* (heterozygote).

11.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Which plants did Gregor Mendel study? Why did he choose these plants?
2. What do F_1 and F_2 mean?
3. **Distinguish** between:
   (a) a dominant and a recessive trait
   (b) a homozygous and a heterozygous organism
   (c) genotype and phenotype.
4. In a punnett square how are the following represented:
   (a) the allele for a dominant trait
   (b) the allele for a recessive trait?

Skill builder

5. Mendel crossed some pure-breeding (homozygous) short pea plants with some pure-breeding tall pea plants and noted how many of the plants produced were short.
   (a) **Identify** the independent variable in Mendel's experiment.
   (b) **Identify** some variables that Mendel would have needed to control in this experiment. (Hint: What else might affect the height of pea plants apart from their genotype?)
   (c) **Explain** why it was important for Mendel to use many pea plants.
   (d) **Justify** why it was important for Mendel to control which plants were crossed.
   (e) Imagine that computers and the internet had been available in Mendel's time. **Evaluate** the impact this would have had on his research and the acceptance of his ideas.
6. Mendel had pure-breeding yellow seed (a dominant character *Y*) and pure-breeding green seed (recessive *y*) pea strains.
   (a) Draw up a punnett square representing a cross between heterozygous yellow seed peas.
   (b) What are the ratios of the genotypes and phenotypes of the offspring?
7. In pea plants red flower colour is dominant over white flower colour. A red-flowered plant with
8. genotype *RR* is crossed with a white-flowered plant with genotype *rr*.
   (a) What are the genotypes and phenotypes of the plants raised from their seeds?
   (b) Use a punnett square to perform a cross between two heterozygous red plants with genotyper). What are the ratios of the different phenotypes?
9. When red carnations are crossed with white carnations, pink carnations are produced. Neither the red nor pink flower colour is dominant. The genotype for red flowers is *RR*, white is *WW* and pink is *RW*.
10. Use a punnett square to **predict** the chance of producing a pink-flowered plant when:
   (a) a plant with red flowers is crossed with a plant with pink flowers
   (b) 2 plants with pink flowers are crossed.

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Complete this digital doc: Worksheet 11.4: Mendel's experiments (doc-12809)

11.5 Different in so many ways

11.5.1 Dominance in alleles

Look around your classroom. Human beings differ in many ways. Many of these differences are the results of the genes we have inherited from our parents, but the environment we have been exposed to since fertilisation also has a role to play.

INVESTIGATION 11.2

How different are we?

AIM: To investigate some of the differences in the phenotype of students

- Copy and complete the table below. You may need to refer to the pictures on the next pages to work out what each characteristic means. You will need data for all students in your class to answer the questions. Using a G-doc spreadsheet or similar is an efficient way of collating the class data.

Name of student	Feature present	Feature absent
Widow's peak?		
Can roll tongue?		
Right thumb over left when clasping hands?		
Cleft chin?		
Right handed?		

Name of student	Feature present	Feature absent
Ear lobes attached?		
Freckles?		
Gap between front teeth?		
Hair naturally straight?		
Colour blind?		

Do you have a widow's peak (left) or a straight hairline (right)?

Do you have a gap between your front teeth?

Discussion

1. Add a column to your table and enter the number of students in your class who have each feature (e.g: the number of students who have a widow's peak).
2. Calculate the percentage of students in your class who have each feature.
3. Construct a column graph showing the percentage of students with each feature.
4. A widow's peak, cleft chin and freckles are dominant traits whereas attached earlobes is a recessive trait. Does the data from your class suggest that dominant traits are more common? Explain why dominant traits may not necessarily be more common in a population than recessive traits.

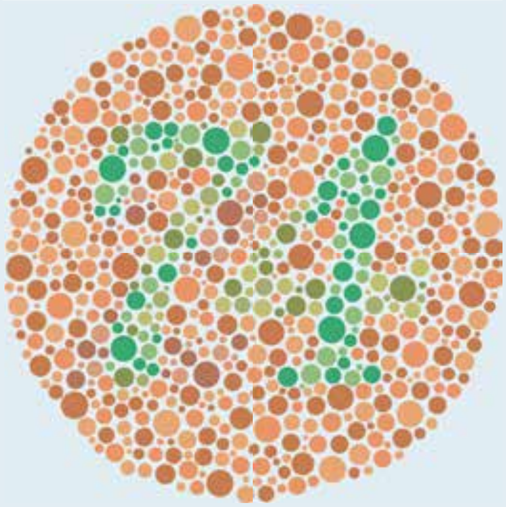
When you clasp your hands, is your right or left thumb on top?

Do you have a smooth or cleft chin (shown below)?

Are your ear lobes attached (left) or detached (right)?

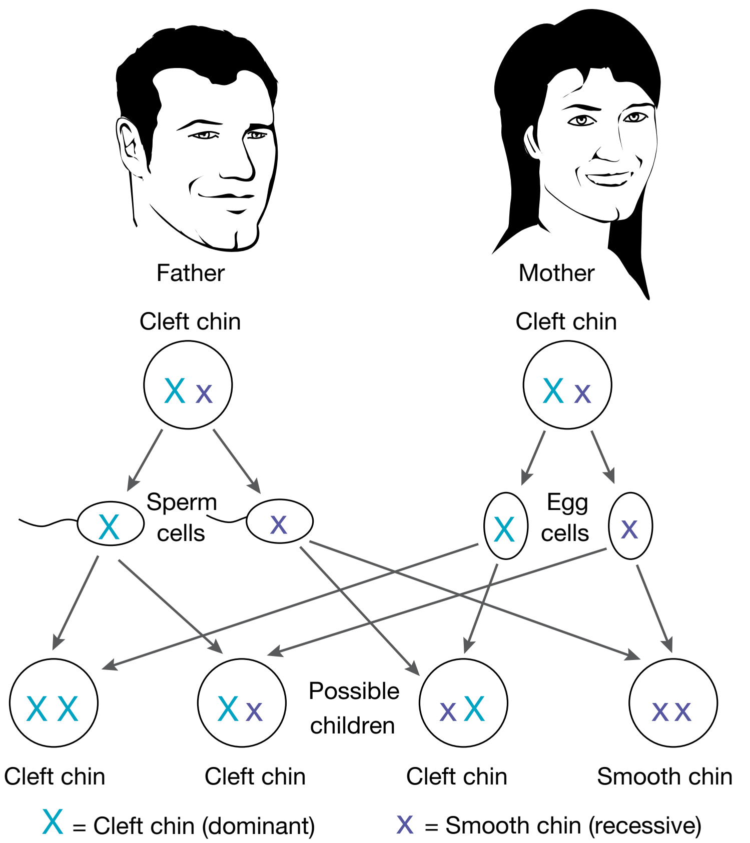
Can you roll your tongue?

If you cannot see the number 74 in the picture below you could be colour blind.



The inheritance of many human features works in a similar way to the inheritance of the characteristics Mendel studied in peas. For example, you might inherit the same allele of the tongue-rolling gene from both parents and end up being a tongue roller. For some characteristics you might inherit a different allele from each parent. You could inherit the allele for a cleft chin from one parent and the allele for a smooth chin from the other parent. If one trait is **dominant** over the other it wins out. It is expressed even if you have only one copy. A cleft chin is a dominant feature, so if you inherited the cleft chin allele from one of your parents you would end up with a cleft chin. You need to remember though that your parents may display a dominant feature, such as a cleft chin, but they themselves may have only one copy of that allele. So that allele may not necessarily have ended up in the gamete from which you were created, and thus may not have been in the cells that make up your body. The following diagram shows how a man and a woman who have a cleft chin can end up with a child with a smooth chin.

A man and a woman who both have a cleft chin can have a child with a smooth chin.



11.5.2 The Human Genome Project

In 1990 an international collaboration project aimed at identifying all the genes in human DNA began. The project was coordinated by the US Department of Energy and National Institute of Health. Australia contributed to the project. In 1995 a facility for DNA sequencing was established in Australia (the Australian Genome Research Facility Ltd).

It was expected to take about 15 years to determine the sequence of about 3 billion bases, then identify all the genes in human DNA. Over the duration of the project significant technological advances were made and processes that were slow and laborious at the beginning of the project could be carried out in a fraction of the time a few years later. With laboratories in various parts of the world working on the same project, technological advances made by one team could be shared with other teams and this contributed to the speed with which techniques evolved. A map covering almost all the gene-containing regions of the genome was announced in 2003, on the fiftieth anniversary of the publication of the structure of DNA. Work is continuing to gain further understanding of the instructions coded in the genome.

One of the positive outcomes of the Human Genome Project is that researchers can now identify the genes responsible for particular genetic disorders in a fraction of the time it used to take. Also, more than 2000 genetic tests are now available to diagnose diseases. As we make more sense of the information revealed by the Human Genome Project it is likely that further advances will be made and new products will continue to be developed.

One of the aims of the Human Genome Project was to sequence the bases in human DNA.

11.5.3 The environment matters too!

Our appearance, personality and many aspects of our health are affected by our genetic make-up, but what happens to us throughout our life can also have a large impact on the way we look and behave, as well as how our body functions. Your height and weight are determined by a combination of genetic factors as well as the food you eat. Type 2 diabetes (the type of diabetes that usually starts in middle age or later) tends to run in families. Certain alleles increase your chance of getting this type of diabetes, but regular exercise and a healthy diet can delay its onset even in genetically predisposed individuals. Any non-genetic factor that influences the phenotype of an individual is referred to as an environmental factor. That can include things such as exposure to pollution, temperature, diet, the amount of water available.

Twins are often used in studies that attempt to tease out whether environmental or genetics factors are more important in determining particular characteristics. Identical twins form from the same zygote splitting into two. They are genetically identical. Differences between identical twins are the result of environmental factors. Fraternal twins form from two different zygotes. Two different eggs are each fertilised by a different sperm cell, so fraternal twins are genetically no more similar than any pair of siblings. A researcher trying to determine if a disease has a genetic basis might analyse data and calculate the incidence of the disease in individuals whose fraternal twins have the condition, then compare this to data for identical twins. Twins that are of particular interest to researchers are identical twins that were separated soon after birth as they have been exposed to different environmental conditions for most of their life.

INVESTIGATION 11.3

How does the environment affect phenotype?

AIM: To investigate how the environment affects phenotype

***You will need*:**

10 seedlings grown from cuttings of the same plant
potting mix
2 small pots

- Plant five of the seedlings in pot A and the other five in pot B.
- Place pot A in a dark cupboard and pot B near a window.
- Leave the plants undisturbed for two weeks. Water both pots when necessary. Ensure you use the same amount of water for both plants. After two weeks compare the plants in both pots.

Discussion

1. Copy and complete the following table.

	Pot A	Pot B
Number of seedlings that are still alive		
Colour of leaves		
Average height of seedlings		
Average number of leaves per seedling		

2. Explain how you calculated the average number of leaves and the average height of the seedlings.
3. In this experiment:
   (a) what is the independent variable
   (b) what is the dependent variable
   (c) which environmental factors were controlled?
4. Why is it important to use seedlings grown from cuttings of the same plant for this experiment?
5. Why were five seedlings planted in each pot?
6. Explain why this experiment demonstrates that environmental factors play a part in determining the phenotype of an organism.

11.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

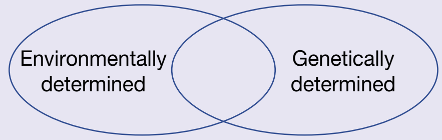
Remember

1. Are the following true or false? Correct any false statements.
   (a) Recessive traits are very rare.
   (b) Phenotype depends only on the genetic make-up of an organism.
   (c) If you have two copies of an allele for a recessive trait the trait will be expressed.

Think

2. The Human Genome Project was coordinated by the US Department of Energy and National Institute of Health but it involved teams of scientists and research facilities from around the world.
   (a) What was the purpose of the project?
   (b) Why was it necessary to involve teams from around the world for this project?
   (c) **Discuss** the advantages and disadvantages of making a project international for the country leading the project.
   (d) What would be the benefits and disadvantages of participating in an international project for the countries that are not leading the project?
   (e) **Outline** two medical advances that are ‘spin-offs’ from the Human Genome Project.

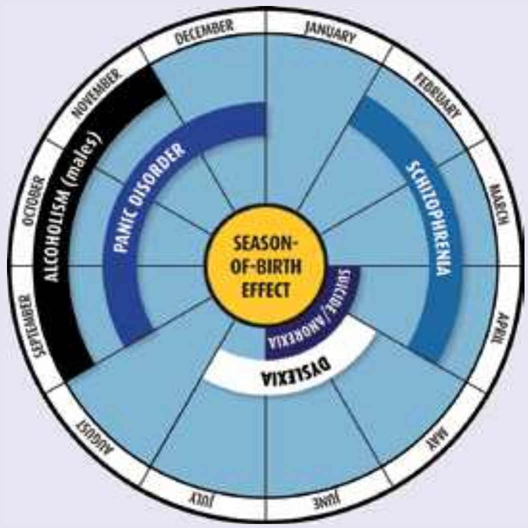
3. Copy the Venn diagram at right into your book and use it to **classify** the list of characteristics according to whether they are genetically determined, environmentally determined or both.



Characteristics:
(a) Widow's peak
(b) Scar on face
(c) Short sightedness
(d) Weight
(e) Ability to speak French
(f) Height
(g) Freckles
(h) Eye colour
(i) Skin colour
(j) Ability to roll tongue

4. Schizophrenia is a mental illness. For identical twins, if one twin has schizophrenia there is about a 47 per cent chance that the other twin will also have the disease. For fraternal twins the chance is only 14 per cent.
   (a) **Explain** how this data supports the idea that schizophrenia is caused by a combination of genetic and environmental factors.
   (b) Study the diagram at right.
      (i) **Interpret** the diagram. What does it show?
      (ii) **Assess** whether the data shown in the diagram at right support the idea that schizophrenia is genetically determined.
5. **Propose** how IQ test results from fraternal and identical twins might be used to determine to what extent intelligence is genetically determined.
6. Use the table below to answer the questions that follow.

An increased risk of some disorders in people in the northern hemisphere is linked to their date of birth.



Dominant trait	Recessive trait
Free ear lobes	Attached ear lobes
Mid-digital hair present	Mid-digital hair absent
Normal skin pigmentation	Pigmentation lacking (albinism)
Non-red hair	Red hair
Rhesus positive (Rh +ve) blood	Rhesus negative (Rh –ve) blood
Dwarf stature (achondroplasia)	Average stature
Widow's peak	'Straight' hairline

(a) Find the probability (chance) of Sally (who is homozygous for dwarf stature) and Tom (who has average stature) having a dwarf stature child.
(b) Find the probability of Fred (who is heterozygous for dwarf stature) and Suzy (who has average stature) having a dwarf stature child.
(c) What is the chance of two parents who are both heterozygous for free ear lobes having a child with attached ear lobes?
(d) Michael is heterozygous for mid-digital hair, whereas Debbie does not have mid-digital hair. What is the chance of their children having mid-digital hair?

7. People often talk of brown eyes being dominant to blue eyes, but the inheritance of eye colour is complex. There are three major eye-colour genes, two on chromosome 15 and one on chromosome 19. An unknown number of other genes play a lesser role, making it possible for two blue-eyed parents to produce a brown-eyed baby. The following table gives a simplified account of the effect of the main three genes.

Chromosome location	Name of gene	Possible alleles
15	Bey1	Central brown (C) dominant to 'not brown' (c)
15	Bey2	Brown (Br) dominant to blue (br)
19	Gey	Green (G) dominant to blue (g)

How might brown-eyed parents produce a blue-eyed baby? (*Hint:* Work out combinations of the parent's alleles first, i.e. *Cc*.)

Investigate

8. **Investigate** one of the genetic conditions listed below. Briefly describe the disease. Is it dominant or recessive?
Huntington's disease, Tay-Sachs, cystic fibrosis, fragile X syndrome, PKU
9. Find out about Dr Neubauer's research on identical twins separated at birth. **Assess** whether this type of research is ethical and whether it has the potential to benefit society.
10. Find out more about the Human Genome Project. What are some of the implications of the project?

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Complete this digital doc: Worksheet 11.5: Dominant and recessive (doc-12810)

11.6 DNA: the blueprint of life

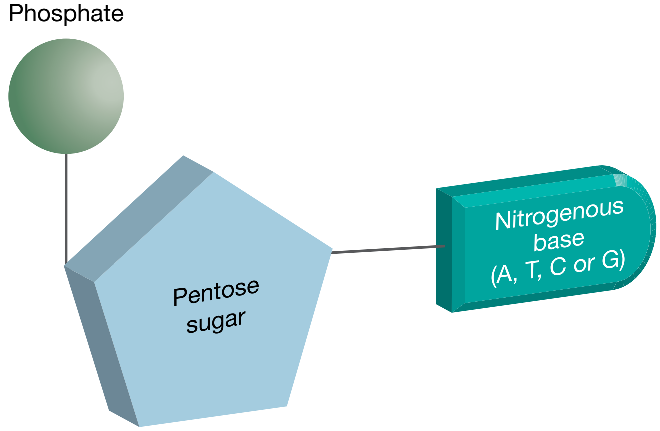
11.6.1 The race for the double helix

You have probably heard about DNA being used as evidence to convict criminals, or to show that a man is the father of a child. It is difficult to imagine that 100 years ago not a great deal was known about DNA. In fact the structure of DNA was only discovered in 1953. This discovery had a huge impact on biology and society as a whole.

In the early 1950s the race was on to discover the structure of DNA. Quite a few clues were available. DNA had been successfully extracted from the nucleus of cells, and biologists knew that chromosomes contain DNA. In 1929, Phoebus Levene had shown that DNA was made up of repeating units called nucleotides. Each nucleotide consists of three parts: a sugar, a phosphate group and a nitrogenous base. He had worked out that there were four different bases: adenine (A), thymine (T), guanine (G) and cytosine (C).

In 1950, Edwin Chargaff discovered that in a DNA molecule the amounts of thymine and adenine are always the same, and the amounts of

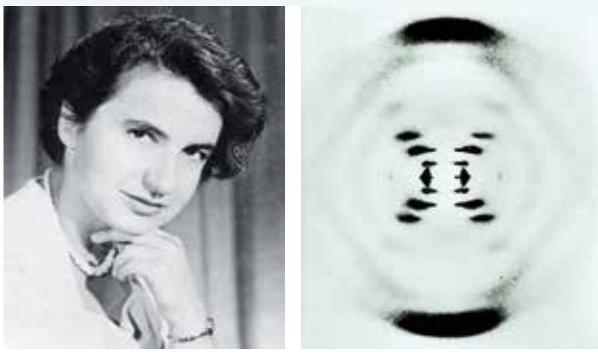
A nucleotide



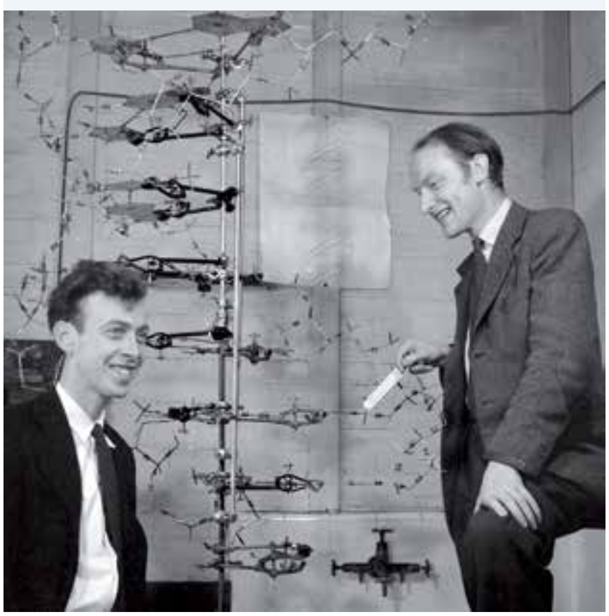
cytosine and guanine are also the same. What was missing was an understanding of the structure of DNA, a model that would show how the pieces connected.

An important clue to this puzzle was provided by an X-ray diffraction picture taken by Rosalind Franklin. The picture, shown to Watson and Crick without Franklin's knowledge, provided important information about the shape of the DNA molecule. Watson and Crick hypothesised that the DNA molecule had the shape of a double helix. They constructed a model that showed that a DNA molecule was like a twisted ladder. The sides of the ladder are made up of alternating sugars and phosphate units. The steps of the ladder consist of nitrogenous bases. Each step is made up of two bases and the bases are attached to the sugar units that are part of the sides of the ladder. The reason that there is always the same amount of A and T and C and G is because that is the way the bases pair up in the DNA molecule. There is always an adenine base opposite a thymine base and a cytosine base opposite a guanine base. Understanding this was very important because it helped explain how identical copies of DNA molecules can be produced when cells divide.

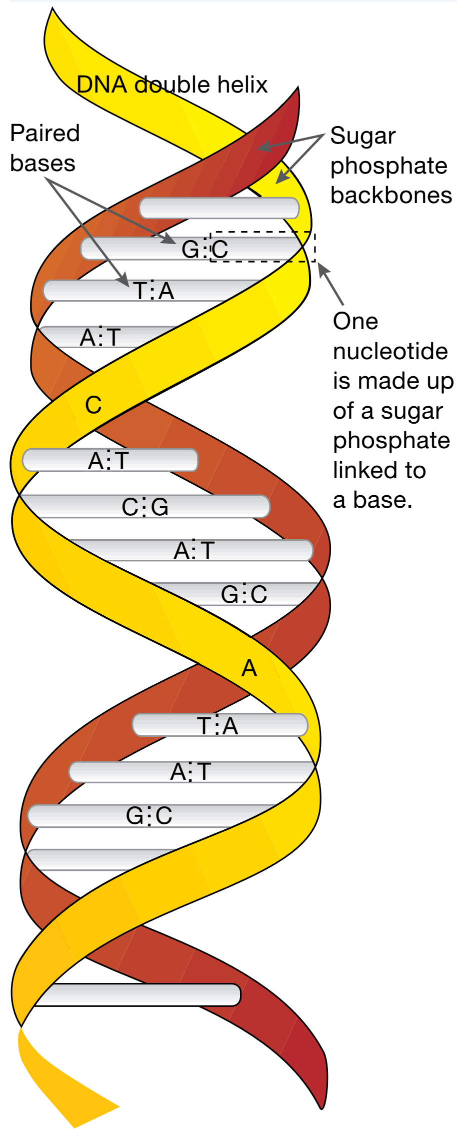
Rosalind Franklin took this X-ray diffraction picture of a molecule of DNA. It gave important clues about the shape of the molecule.



James Watson and Francis Crick with their model of a DNA molecule



In a DNA molecule, nucleotides are linked together in different orders to make up a single strand of DNA, then each strand is bonded to a second strand to form double-stranded DNA.



INVESTIGATION 11.4

Working with DNA

AIM: To extract DNA from ground wheatgerm

You will need:

1 teaspoon of finely ground wheatgerm
14 mL of isopropyl alcohol (or equivalent)
1 mL of liquid detergent
20 mL of hot tap water (50–60 °C)
test tube
measuring cylinders
rubber stopper
test-tube rack
Pasteur pipette and bulb
glass stirring rod

- Draw a table in your book, allowing room for observations in the form of a diagram: immediately after adding the alcohol; at 3- and 15-minute intervals; and then after you have collected and removed the DNA.
- Add the wheatgerm and hot water to a test tube. Twist the stopper in and shake for 3 minutes.
- Add 1 mL of detergent and mix gently with the glass rod for about 5 minutes. Do not create foam.
- If you do create foam, suck it out with the Pasteur pipette.
- Tilt the tube at an angle and slowly pour in the alcohol so that it sits at the bottom.

CAUTION: DO NOT MIX!

- Fill in your observations.
- Fill in observations after 3 minutes and again after 15 minutes.
- Collect the DNA with the glass rod. Feel it with your fingers and make your final observations.

Discussion

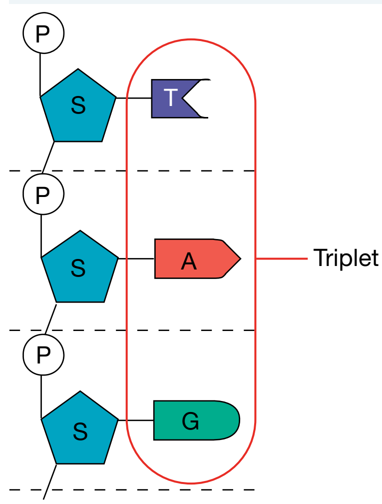
1. What colour did you expect DNA to be? Why do you think it was the colour that you observed?
2. How could you confirm if it really was DNA?

11.6.2 Unravelling the code

Our DNA codes for many of the characteristics that make us who we are, but how does it work? How does a chemical molecule inside the nucleus of cells control features such as height, eye and hair colour and our likelihood of developing certain diseases? It has to do with proteins!

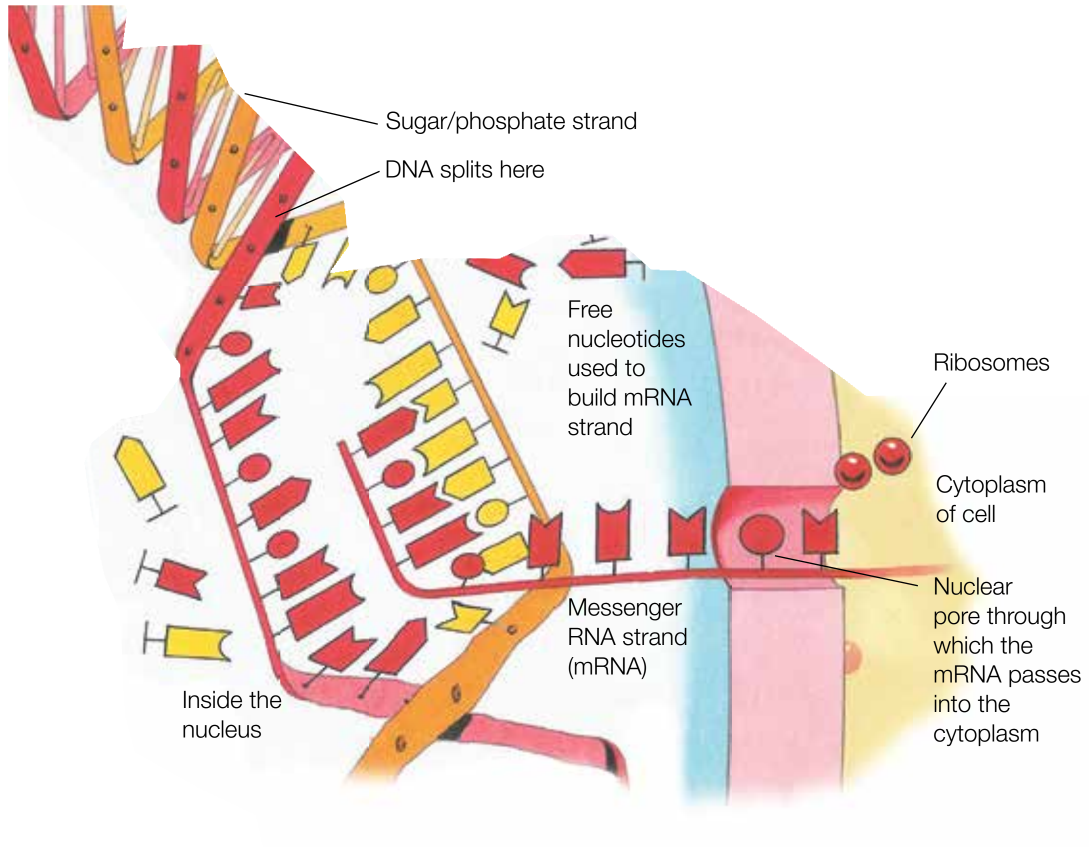
An organism's DNA contains the instructions for making all the proteins that it needs to keep it functioning properly. The instructions are in the form of a code that has to do with the sequence of bases in the DNA molecule. Only one strand of the DNA molecule is 'read'. A particular sequence of bases along the DNA molecule is the start of the code for making a particular polypeptide (proteins are made from one or more polypeptides). From that point on, the code is read by looking at the sequence of bases in groups of 3. Each set of 3 bases is called a triplet. Each triplet codes for a particular amino acid. There is some repetition since 4 bases can organise themselves in 64 different ways and there are not that many different amino acids.

The DNA code is read three bases at a time.



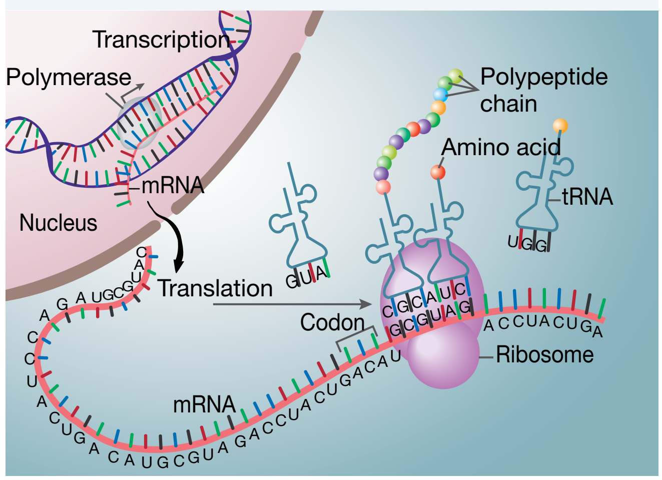
In a process called transcription the DNA unzips and one of the strands of DNA is used as a template to make a molecule called messenger RNA (mRNA). This molecule leaves the nucleus and travels to the cytoplasm of the cell where there are structures called ribosomes. These are involved in making proteins.

Transcription



The ribosomes lock on to the mRNA and the next step called translation begins. In the cytosol of the cell there are molecules of transfer RNA (tRNA). Each tRNA molecule has an amino acid attached and a particular sequence of bases. As the ribosome moves along the mRNA molecule, tRNA molecules with the corresponding sets of bases bring along the amino acid they are carrying. The amino acids then link together to form a chain of amino acids — a polypeptide chain. Further processing will eventually produce a protein.

Transcription and translation



The table on the next page can be used to determine which amino acid sequence a piece of DNA codes for. The table is based on the sequence of bases in the ‘sense’ or coding strand of the DNA molecule. Just to make things confusing it is actually the other strand (the ‘antisense’) strand that is used as the template to construct the mRNA. Make sense?

Why are proteins so important?

Proteins form parts of cells. The muscle tissue in your heart contains special proteins that can contract, enabling blood containing haemoglobin and hormones to be pumped through the body. Haemoglobin is

The triplet code

First base		Second base							
		T		C		A		G	
T		TTT	Phe (F)	TCT	Ser (S)	TAT	Tyr (Y)	TGT	Cys (C)
		TTC	Phe (F)	TCC	Ser (S)	TAC		TGT	
		TTA	Leu (L)	TCA	Ser (S)	TAA	**STOP**	TGA	**STOP**
		TTG	Leu (L)	TCG	Ser (S)	TAG	**STOP**	TGG	Trp (W)
C		CTT	Leu (L)	CCT	Pro (P)	CAT	His (H)	CGT	Arg (R)
		CTC	Leu (L)	CCD	Pro (P)	CAC	His (H)	CGC	Arg (R)
		CTA	Leu (L)	CCA	Pro (P)	CAA	Gin (Q)	CGA	Arg (R)
		CTG	Leu (L)	CCG	Pro (P)	CAG	Gin (Q)	CGG	Arg (R)
A		ATT	Ile (I)	ACT	Thr (T)	AAT	Asn (N)	AGT	Ser (S)
		ATC	Ile (I)	ACC	Thr (T)	AAC	Asn (N)	AGC	Ser (S)
		ATA	Ile (I)	ACA	Thr (T)	AAA	Lys (K)	AGA	Arg (R)
		ATG	Met (M) **START**	ACG	Thr (T)	AAG	Lys (K)	AGG	Arg (R)
G		GTT	Val (V)	GCT	Ala (A)	GAT	Asp (D)	GGT	Gly (G)
		GTC	Val (V)	GCC	Ala (A)	GAC	Asp (D)	GGC	Gly (G)
		GTA	Val (V)	GCA	Ala (A)	GAA	Glu (E)	GGA	Gly (G)
		GTG	Val (V)	GCG	Ala (A)	GAG	Glu (E)	GGG	Gly (G)

a protein that carries oxygen necessary for respiration. Many hormones are proteins. Hormones, such as insulin or adrenaline, influence our cells' activities. Most enzymes are proteins. Enzymes control metabolic activities such as chemical digestion and respiration. Plants also rely on the action of hormones and enzymes for survival. Hormones control the growth of plants and photosynthesis depends on enzymes.

HOW ABOUT THAT!

Hijack

Sometimes the 'machinery' used in transcription and translation is hijacked by viruses. Viruses cannot reproduce by themselves. Instead, they attach to a host cell, inject their own genetic material into the cell, and then use the cell's machinery to express their genes and make millions of *clones* of themselves. The cell makes millions of copies of the virus's DNA (or RNA) and the necessary structures of the virus until functioning virus particles are assembled. Eventually, the host cell may burst open and die, releasing millions of virus particles to infect other cells within the organism.

11.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Outline** the contribution made by each of the following scientists to discovering the structure of DNA:
   (a) Phoebus Levene
   (b) Edwin Chargaff
   (c) Rosalind Franklin
   (d) James Watson and Francis Crick.
2. List the components of a nucleotide.

3. If we compare a DNA molecule to a twisted ladder, which components form:
   (a) the steps of the ladder
   (b) the sides of the ladder?
4. What shape is a DNA molecule?
5. **Identify** the main type of molecule that genes code for.
6. Which DNA bases pair up together?
7. Copy and complete the following statements:
   (a) Polypeptides consist of a string of ____________.
   (b) A group of ____________ bases codes for a particular amino acid.
   (c) In transcription one of the DNA strands is used as a template to produce a strand of ____________ RNA.
   (d) ____________ RNA molecules have an amino acid attached.
8. How do viruses replicate?

Skill builder

9. A number of diagrams in this subtopic include part of a DNA molecule. For each diagram write down one piece of information about DNA that is shown in this diagram but not the other diagrams.
10. A strand of DNA has the following bases: AGCTATATCGA. **Deduce** the bases on the matching (complimentary) strand.
11. The bases for two small strands of DNA are shown below. They are the bases for a small section of the gene that codes for the manufacture of one of the polypeptides in a protein called haemoglobin.
    Strand obtained from person A: CTG ACT CCT GAG
    Strand obtained from person B: CTG ACT CCT GTG
    (a) Use the table on the previous page to **deduce** the amino acid sequence that each of the sections of DNA shown above will produce.
    (b) The amino acid sequence leu - thr - pro - val results in the disease sickle-cell anaemia. Which person has this condition?
12. The picture shows a model of DNA that Watson and Crick constructed. **Outline** some reasons why scientists construct models such as the one shown in the picture.

Investigate

13. James Watson (co-discoverer of the structure of DNA) and Craig Venter were both involved in investigating the human genome.
14. Find out more about science as a human endeavour by following their two different stories of genome exploration, what they have in common, and how and why they clash. Start by clicking on the **James Watson** weblink in the Resources tab.
15. Use the **DNA ownership** weblink in the Resources tab to watch an interview with James Watson in which he raises some interesting issues about the ownership of scientific discoveries that are worth reflecting on and discussing with other students.
16. Draw a timeline to show the rate of identification of human genes. A computer database called OMIM (On-line Mendelian Inheritance in Man) keeps a regular update. Use the **OMIM** weblink in the Resources tab to access the OMIM website.

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Explore more with this weblink: DNA ownership

Explore more with this weblink: OMIM

Explore more with this weblink: James Watson

Complete this digital doc: Worksheet 11.6: DNA (doc-12811)

11.7 Mutations

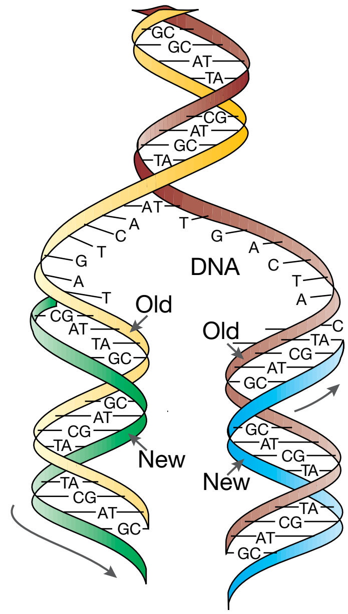
11.7.1 Making exact copies

Earlier in this topic we saw that in order for cells to divide, the DNA in the nucleus needs to replicate. In most instances the DNA is copied exactly but sometimes errors creep in and are not detected.

In mitosis each daughter cell ends up with the same number and type of chromosomes as the parent cell. The DNA therefore needs to replicate (copy itself) and the new cells need to have identical copies of the DNA in the original cell.

DNA replication begins when enzymes 'unzip' the paired strands of DNA somewhere along the DNA molecule. Each unzipped section of DNA serves as a template to start building a complementary strand of DNA. An enzyme called DNA polymerase adds matching nucleotides to the exposed nucleotides of the unzipped sections. The nucleotides join together and the process continues until the whole molecule has been unzipped and complementary strands have been built on each exposed strand. At the end of DNA replication, each double-stranded DNA molecule contains one old and one new strand of DNA.

A simplified view of DNA replication. Each of the two strands acts as a template for one new strand to be produced.



Arrows denote direction of synthesis.

11.7.2 Mutations

The process of DNA replication has a number of check points to detect any mistakes that may be made, so that they can be corrected or destroyed. Sometimes, however, the mistakes get through this screening process. When this happens, we say that a mutation has occurred.

Mutations can happen by pure chance or be due to a particular cause such as ultraviolet radiation or too much exposure to X-rays. Any factor that triggers mutations in cells is called a **mutagen**. The chemicals formalin and benzene (which used to be common in pesticides) are examples of mutagens.

Changes in the letters can change a word's entire meaning. Changes like these in the DNA sequence change the 'meaning' of the code. Minor mutations in body cells often seem to have no adverse effect. The body's immune system usually recognises the changed cells and destroys them quite readily.

However, in some cases the mutation has a more severe effect. A necessary enzyme, for example, is not made or a faulty version is produced. Too much or too little of a particular protein could be the problem. In cases of hereditary haemochromatosis a faulty gene affects the production of a protein that is involved in regulating iron levels in blood. People who have this condition may have elevated iron blood levels which can lead to damage of organs including the liver, heart and pancreas.

Polydactyly (having more than 10 fingers and toes) is usually due to a DNA mutation.

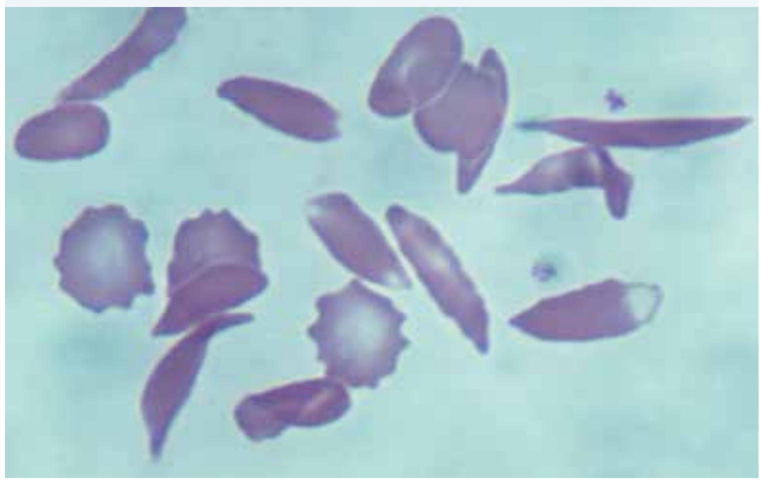
Certain mutations result in uncontrolled cell division, which can result in cancerous **tumours**. Plants can suffer from tumours too.

Not all mutations are harmful. Some species of organisms, such as insects, depend on them for survival. Pesticides may kill the majority of insects sprayed, but there will be some that have slight variations or mutations in their genes, which give them resistance. The mutated genes are passed on to the offspring, who will gain that resistance too. The insects without the resistance will die out. Resistance by bacteria to antibiotics occurs in a similar way. While resistance in certain insects may be good news for them, resistance to antibiotics in bacteria means it can become very difficult to treat diseases caused by these bacteria.

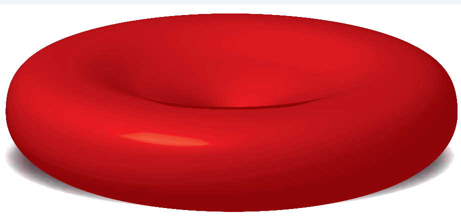
In humans the sickle-cell mutation can be both detrimental and beneficial. In this mutation, an adenine base is replaced by a thymine base in the gene that codes for one of the haemoglobin polypeptides. Haemoglobin is a protein found in red blood cells. A person who inherits a copy of the sickle-cell mutation from just one parent may have mild anaemia or no symptoms at all. If a copy of the mutated DNA is inherited from both parents the result is sickle-cell anaemia. People with this condition have misshapen red blood cells. Their red blood cells tend to clump together, get damaged easily and block blood vessels. They experience pain, swollen hands and feet, tiredness, frequent infections and may also grow more slowly and have vision problems.

The sickle-cell mutation is harmful if two copies of the sickle-cell allele are inherited. It can be beneficial if only one copy is inherited though. Individuals with one copy of the sickle-cell allele are less likely to die from malaria. Malaria is a disease transmitted by a species of mosquito. It is very common in many parts of Africa, Asia and South America. The micro-organism that causes malaria cannot grow as well in the blood of people who have one copy of the sickle-cell allele. Thus, in this instance, the mutation is beneficial.

A misshapen red blood cell caused by sickle-cell anaemia



Sickle-cell anaemia: a mutation in a gene causes red blood cells to have an unusual shape.



DNA sequence (sense strand)	**Amino acid sequence**
…-CTG ACT CCT GAG-…	leu - thr - pro - glu

Appearance of blood cells
Normal, doughnut-shaped blood cells

DNA sequence (sense strand)	**Amino acid sequence**
…-CTG ACT CCT GTG-…	leu - thr - pro - val

Appearance of blood cells
Sickle-cell shaped blood cells

Passing them on

If someone's sperm or ovum carries a DNA abnormality, there is a chance of their child being affected. Inherited gene and chromosome abnormalities result in genetic disorders. These can be slight, such as being red–green colourblind, or more severe, such as haemophilia, a disorder in which blood does not clot.

A chance event

About 1 in 2500 people suffer from a genetic disorder called cystic fibrosis (CF). What is the chance of a particular person getting it and why is it important to know?

The faulty recessive CF allele is on chromosome number 7. One amino acid in a chain of 1480 amino acids is not produced, causing large amounts of thick mucus to be produced by cells lining the lungs and in the pancreas where digestive juices are secreted. The mucus interferes with the working of the respiratory and digestive systems. Infection readily occurs and sufferers tend to have a shortened life span.

Since the identification of the defective allele in 1989, the DNA of parents can be analysed to find out if they are one of the one in 25 people that carry the defective gene.

Why is knowing whether you are a carrier so important? For parents who are carriers for CF, the chance of each child suffering from the disorder is at least one in four.

Counselling can help carrier parents decide whether to take the chance and have a child. If they choose to go ahead, genetic testing can determine the genotype of the fetus and therefore whether it does not have the condition, is a carrier, or has the condition. What would you choose to do if the fetus had the condition?

HOW ABOUT THAT!

Today we know that X-rays can cause mutations in cells. Frequent exposure to high doses of X-rays can cause cancer and damage to egg and sperm cells. Before the dangers of overexposure to X-rays were discovered it was not uncommon for X-ray machines to be found in shoe shops. X-ray images of the feet inside the shoes were used to check that the shoes fitted properly.

A swarm of mutants!

Mutants have been studied extensively by geneticists over the years. They can reveal how various traits are genetically controlled, and how they are inherited.

Fruit fly (*Drosophila*) are often used in genetics studies. They have naturally occurring mutations such as orange-eyed, white-eyed, yellow-bodied, ebony-bodied, and finally, the leg-headed fly! The normal fruit fly (which is called *wild-type*) has small antenna consisting of fleshy pads (opposite), while the leg-headed fruit fly has antennae shaped like legs — a mutation.

Normal fruit fly

This fruit fly has legs where its antennae should be.

11.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Draw diagrams to outline how DNA replicates.
2. **Define** the terms 'mutation', 'mutagen', 'beneficial' and 'detrimental'.
3. **Explain** how a tumour forms.
4. (a) How common is cystic fibrosis?
   (b) **Describe** the symptoms of cystic fibrosis.
   (c) On which chromosome is the allele for CF located?
5. **Explain** why the DNA mutation that causes sickle-cell disease can be considered both detrimental and beneficial.

Think

6. **Explain** why it is important for DNA to replicate exactly.
7. Why do radiographers wear special protective clothing and use remote controls for taking X-rays?
8. Suggest examples of mutations that increase chances of survival.
9. The sickle-cell allele is a lot more common among people that live in malaria regions. **Explain** why this might be the case.
10. A short section of DNA is shown below.
    ATGTTTAGTCCATAA
    (a) Use the triplet code table to work out which amino acids this piece of DNA codes for.
    (b) In a substitution mutation two bases are switched. If the fourth base (T) was substituted with A, which amino acid sequence would it code for?
    (c) In a deletion mutation a base is deleted. If the fourth base (T) was deleted, which amino acid sequence would it code for?
    (d) In an insertion mutation an additional base is added. What would happen if the base A was inserted between the fourth and fifth base?
    (e) Sometimes bases can be switched around (an inversion mutation). What would happen if the 7th and 8th base were switched around?

Investigate

11. Research other examples of mutagens.
12. Eating plenty of brightly coloured vegetables is recommended by health professionals for a number of reasons, including the fact that they contain antioxidant vitamins. These vitamins mop up free radicals that could damage DNA, resulting in mutations. James Watson, one of the scientists responsible for proposing the double helix model of DNA has recently warned people about the risks of taking high doses of antioxidant vitamins while undergoing cancer treatment. Find out why by using the **Scientists warn against vitamins** weblink in the Resources tab. Outline the key points made in the article.
13. Use the **Breast cancer** weblink in the Resources tab to watch a video that explains why women who have inherited a particular mutation from one parent have a much higher chance of developing breast cancer. The woman in the video may not develop breast cancer, but she has a much higher chance of doing so than the average woman. The video explains how environmental factors and genetic factors will eventually determine whether she develops breast cancer.

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Explore more with this weblink: Scientists warn against vitamins
Explore more with this weblink: Breast cancer

11.8 Genetics at work

11.8.1 Genetic counsellor

Do you find genetics interesting? There are a range of careers where a good understanding of genetic principles is necessary.

The role of a genetic counsellor is to help people with information about the likelihood of having a child affected by a genetic disease. Often a counsellor is consulted if a couple already has an affected child, or if there is a family history of genetic disease.

Today, greater knowledge of the link between particular **alleles** and disease allows genetic screening. For example, some forms of breast cancer are caused by a particular allele. It is possible to check if an individual's DNA contains this allele and, if it does, the individual may be able to reduce the risk factors in their lifestyle and have more regular screening tests to detect early signs of breast cancer. Genetic counsellors often work in hospitals in collaboration with medical specialists.

A genetic counsellor obviously needs to understand the principles of inheritance and must have a strong interest in health and genetics. Genetics is a rapidly changing area of science, so it is necessary for professionals in this field to keep up with new knowledge that is being discovered in order to give patients current information. Another important skill for a genetic counsellor is the ability to communicate effectively. Genetic counsellors have to explain complex ideas to people who usually have not studied genetics at university. They also need to show compassion and empathy towards their patients.

Pedigree diagrams

A **pedigree** diagram is a type of diagram often used by genetic counsellors. It uses special symbols to represent the individuals in a family and track the incidence of a particular genetic trait in that family.

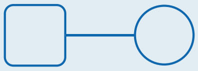
SOME RULES FOR DRAWING PEDIGREE CHARTS

1. **To show the gender of an individual:**

   a square is used to represent a male

   a circle is used to represent a female.

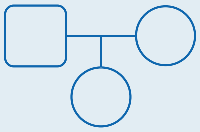
2. **To show the marriage or breeding relationship between individuals:**



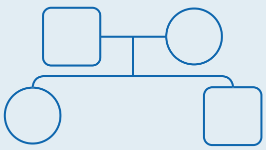
a line connecting the male and female is used to represent a breeding couple or marriage.

3. **To show the offspring relationships:**

a line from the breeding couple/marriage line indicates children.

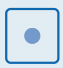


For example, an only child (in this case, a daughter)



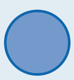
or two children (in this case, a daughter and son).

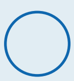
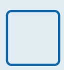
4. **To show carriers of traits, the symbol may have a dot.**

 female carrier  male carrier

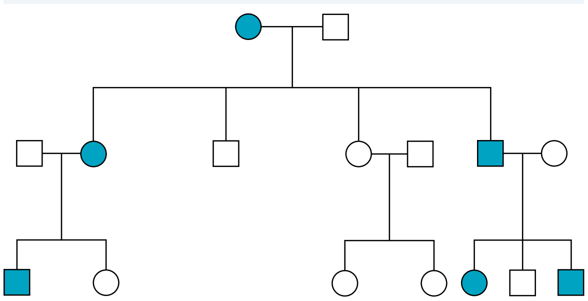
It is important to note, however, that carriers' symbols are not always dotted and may appear blank.

5. **To show which individuals show a particular trait, an individual's symbol is shaded and this information is shown in a key next to the pedigree chart.**

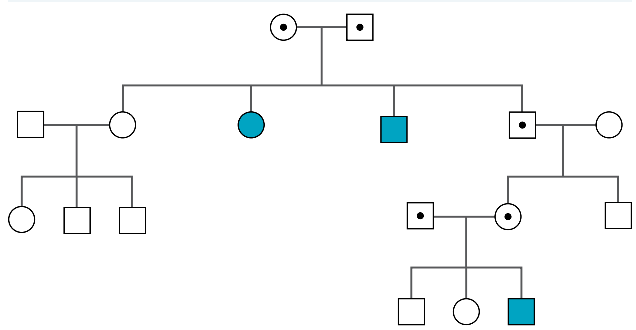
 female with trait  male with trait

 female without trait  male without trait

A possible pedigree pattern for the inheritance of Huntington's disease, a dominant condition. Each child of an affected parent has a 50% chance of being affected; so approximately half will be affected and half won't.



A possible pedigree pattern for a recessive gene such as cystic brosis. Two unaffected parents can produce affected children. The parents in this case are carriers.



11.8.2 Forensic scientist

DNA fingerprinting is one of the powerful new techniques available for crime scene investigation. Blood, sweat, semen and saliva all contain DNA. A DNA fingerprint is created by analysing the pattern of one kind of DNA sequence present. There is little chance that this pattern is shared by unrelated people.

On TV you'll see one or two forensic scientists running a range of tests; the reality is that a whole group of expert chemists, biochemists, pathologists and physicists might work together to analyse evidence from a crime scene.

To create a DNA fingerprint, first DNA is purified from biological material found at the crime scene, and then cut at particular sites. Each DNA fingerprint is almost unique, with the chance of unrelated individuals sharing a DNA fingerprint being very low.

11.8.3 Geneticist

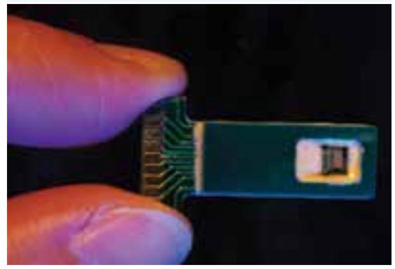
The bulk of the work carried out in genetics laboratories deals with genetic disorders rather than crime solving. While genetic counsellors discuss the results of genetic tests with patients, other scientists work behind the scenes to design and carry out genetic tests. A type of a test carried out in a genetics laboratory involves a gene probe to find out if an individual is carrying the allele for a disease such as cystic fibrosis. A gene probe is a short sequence of DNA that contains the complementary bases for the allele responsible for the condition. To do this test, a sample of DNA must first be obtained from the individual. The DNA strands are separated and the probe is mixed with the sample. If the DNA and the probe pair up it means the individual is carrying the faulty allele.

11.8.4 DNA chips

A recent development in the area of DNA testing is the use of DNA chips or DNA microarrays. Rather than test a sample of DNA for one gene or a few genes only, it is now possible to test for the presence of a whole range of genes at the same time. A new term has been invented to describe the study of a large number of genes (in some instances all of an organism's genes) at the same time: genomics.

A DNA chip has thousands of little spots. In each spot there are DNA probes for a particular gene. Let's say you wanted to compare which genes are switched on in skin cancer cells and healthy skin cells. You could extract DNA from both types of cells. All the genes that are switched on in each cell can produce the corresponding messenger RNA for the particular sequence of DNA in that gene. The messenger RNA can in turn be used to produce single strands of DNA with a fluorescent label. A different colour label is added to the DNA produced from the healthy cells and cancer cells. The samples of DNA are then added to the DNA chip. Some of the DNA will bind (hybridise) with the gene probes. The DNA that does not hybridise is washed off. By comparing the colour of the dots on the DNA chip it is possible to compare the genes that are switched on in the healthy cells and the cancer cells. Spots that show only the colour that was incorporated into the healthy cell DNA indicate genes that are expressed only in the healthy cells. Both colours will show up for genes expressed in both cells and only the colour used to tag the cancer cells will show up for genes that are expressed only in the cancer cells. The DNA chip is scanned to identify exactly which spots show up each colour and thus determine which gene they correspond to. The data obtained through this test can help doctors select the most appropriate treatment to target a patient's cancerous cells. DNA chips are an example of biotechnology that utilises knowledge uncovered through the Human Genome Project.

A DNA chip.



DNA KITS CAN BRING UNWANTED SURPRISES

A Californian company is marketing a DNA test kit for under $100 that can be ordered and registered online. A container arrives in the mail for the collection of a spit sample. That sample is then shipped back to the lab for testing. The DNA can be tested to determine ancestry and medical information. It can provide information about your chance of developing certain diseases and whether you carry a copy of the allele for particular genetic disorders.

Sometimes the test reveals unexpected information. Carole Kushnir discovered she had a high risk of developing breast and ovarian cancer. She is now having regular tests for breast cancer and she has elected to have her ovaries removed. Karen Durrett discovered that the man she thought was her father actually wasn't. She has since met her real father and her half-sister for the first time. Mrs Durrett found out that, like Mrs Kushnir, she was carrying the BRCA2 gene which greatly increases the chance of developing breast cancer, and a biopsy revealed that she already had breast cancer. Her half-sister also had breast cancer.

There are concerns about the DNA test kits. Contamination may occur as the DNA sample is not collected by trained staff. The industry is unregulated and there are risks associated with providing complex medical information without a doctor or counsellor present.

Source: Philip Sherwell, 'DNA kits can bring unwanted surprises', *Sydney Morning Herald*, 7 January 2013.

11.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

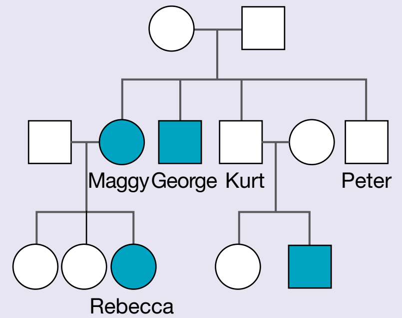
Remember

1. **Describe** the job of a genetic counsellor.
2. Copy the table below. Using an arrow, link each of these with their correct representation in a pedigree:

Male	Marriage
Female	Shaded
Affected	Dark dot in centre
Carrier	Square
Not affected	Offspring
Horizontal line	Circle
Vertical line	Left unshaded

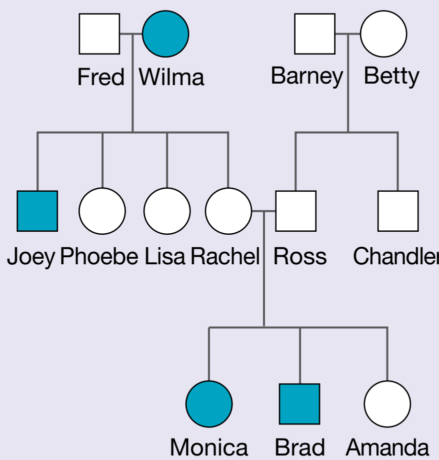
3. What is a DNA probe?
4. What is a DNA chip? What sort of information can it reveal about cells?
5. What causes the coloured dots on the DNA chip?

Shaded individuals show the recessive red hair trait. Unshaded individuals show the dominant dark hair trait.

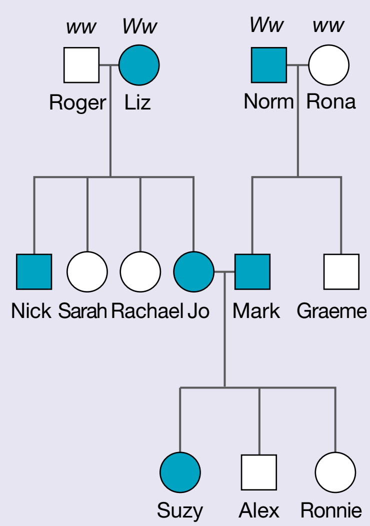


Skill builder

6. (a) Refer to the pedigree of the Jones family, in the diagram at right. The inheritance of dark hair (D) is dominant to the inheritance of red hair (d).
   (b) **Identify** how many females and males are shown in the pedigree chart.
   (c) How many females have the red hair trait?
   (d) **Identify** the genotype of Maggy's parents.
   (e) **Explain** how Maggy inherited red hair, when her parents did not.
   (f) Suggest the genotypes of:
      (i) Peter
      (ii) Kurt
      (iii) George
      (iv) Rebecca.
7. The pedigree at right traces the recessive trait of albinism in a family. The shaded individuals lack pigmentation and are described as being albinos.
   (a) List any observations from the pedigree that support albinism being a recessive trait.
   (b) If the albinism allele was represented as 'n' and normal skin pigmentation as 'N', state the possible genotypes for each of the individuals in the pedigree.



8. The pedigree below right traces the dominant trait, a widow's peak, in a family.
   (a) List any observations from the pedigree that support the widow's peak being a dominant trait.
   (b) If the widow's peak allele was represented as *'W'* and the 'straight' hairline as *'w'*, **identify** the possible genotypes for each of the individuals in the pedigree.
   (c) If Jo and Mark were to have another child, what would be the chance of the child having a widow's peak?
   (d) If Ronnie was to have a child with a man who did not have a widow's peak, **calculate** the probability that their child would have a widow's peak.
   (e) If Norm and Rona were to have another child, **calculate** the probability that they would have a child without a widow's peak.



Think and discuss

9. (a) Choose which words you think best apply to the work of a forensic scientist from the following list of terms: imaginative, methodical, biased, thorough, neutral, dangerous.
   (b) Make a list of words you think would apply to the other types of scientists described above. Do any appeal to you more than others? Why?
10. An allele for a particular condition is made up of DNA with the following base sequence:

AATCGATCGTTCCAT.

What base sequence would be needed for the probe that will identify this gene?

11. Huntington's disease is a genetic disorder. Symptoms do not usually appear until middle age. The first signs of the disease are slight twitching of the fingers and toes. As the disease slowly progresses, the person displays increasingly jerky movements and eventually even speech and swallowing become difficult. A genetic test is available for this condition.
    (a) **Discuss** whether you would choose to be tested for the Huntington gene if there was a history of Huntington's disease in your family. Give reasons for your answer.
    (b) **Assess** whether knowing you had the Huntington gene would affect the choices you make in life.
12. **Discuss** whether it should be illegal for DNA testing kits to be marketed online.
13. Imagine that it was compulsory for people to be tested for a range of genetic conditions and that the results were kept in a database that anyone could access for a fee. **Evaluate** how this would impact on society.
14. Use the **DNA chip** weblink in the Resources tab to find out what an actual DNA chip looks like.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: DNA chip

Complete this digital doc: Worksheet 11.7: Pedigrees (doc-12812)

11.9 Manipulating DNA

Science as a human endeavour

11.9.1 DNA fingerprinting

Genetics is one of the areas of science where new knowledge is being discovered most rapidly. Watson and Crick proposed the double helix model for the structure of DNA in 1953. Since then huge leaps have been made in the area of biotechnology. Today it is possible to compare the DNA of individuals and find out if they are related. Genes can be cut and pasted from one species to another. With biotechnology developing at such a rapid pace it is important for us to stop and think about the ethical implications it brings.

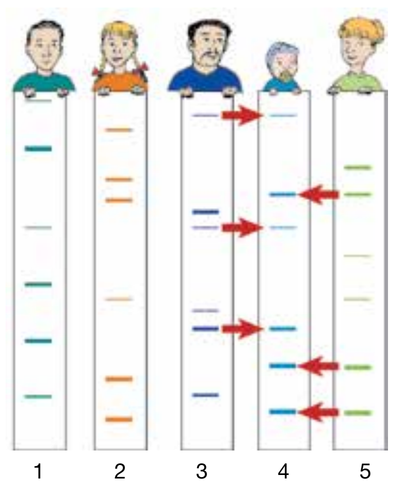
DNA fingerprinting is used in forensic investigations and paternity tests. A sample of DNA is collected and mixed with enzymes that cut the DNA at particular sites. The mixture of DNA fragments is then separated using a technique called electrophoresis. The result is a pattern of bands called a DNA fingerprint. The procedure is explained in the diagram on the next page.

When a paternity test is carried out, the **DNA fingerprint** of the child is compared to the DNA fingerprint of the man thought to be the father. People who are genetically related will have some bands in common in their DNA fingerprints.

Paternity testing made the headlines when a woman claimed that Justin Bieber was the father of her child. Bieber used a paternity test to show he was not the child's father and sued the woman for making the accusations. Paternity testing has also been used in divorce cases where estranged husbands have tried to show that children they had been supporting financially were not actually genetically related to them.

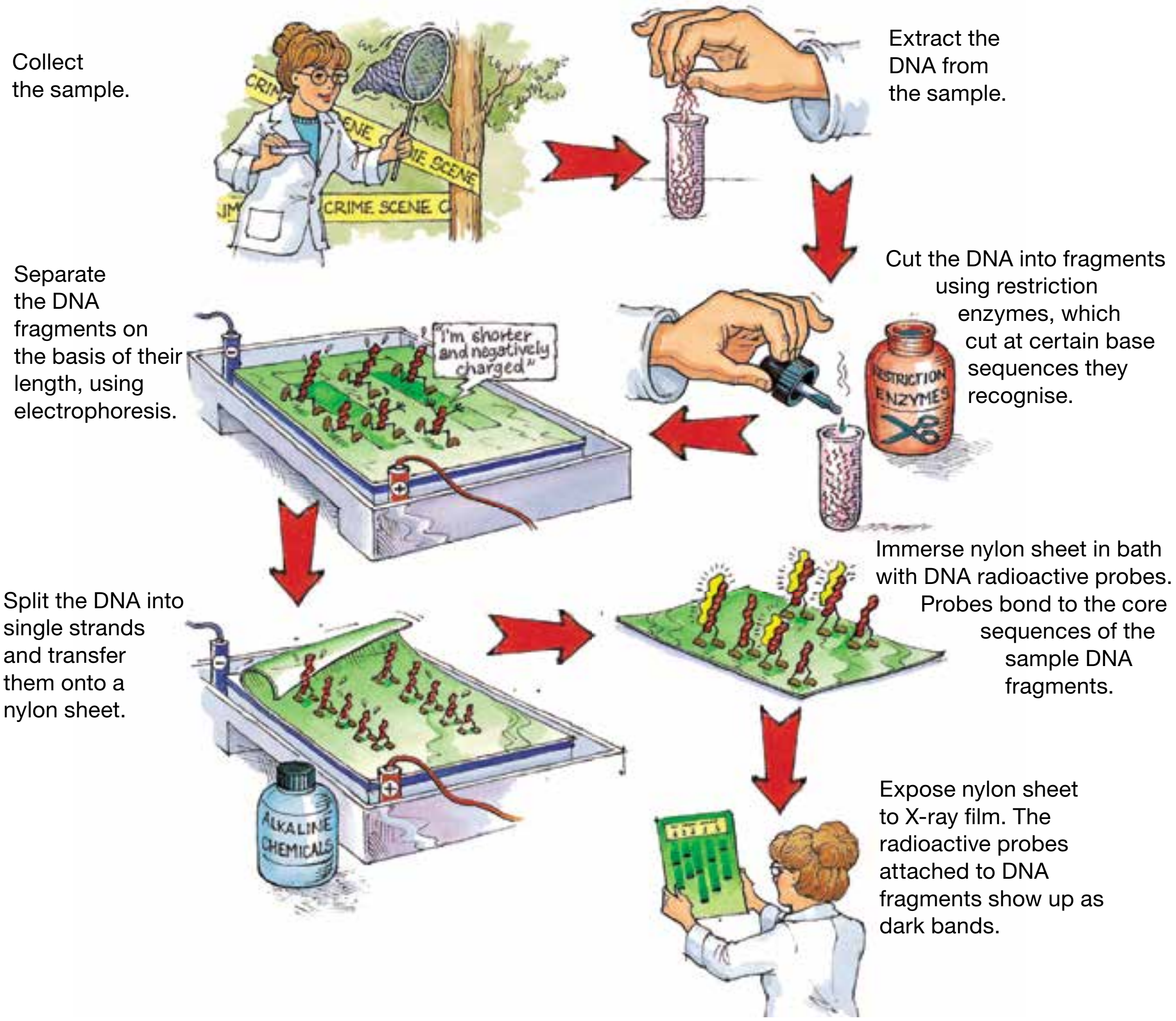
DNA fingerprinting can also be used to compare DNA left at the scene of a crime with DNA collected from a suspect. If the pattern of bands matches there is a high probability that the suspect was at the crime scene. You might wonder how the tiny amounts of DNA in a single hair or a drop of blood can provide useful information.

Who are the parents of person 4? Are persons 1 and 2 related?



In the late 1980s the Polymerase Chain Reaction (PCR) was developed. It is a technique that amplifies tiny amounts of DNA and copies the DNA so that there is enough to use for the various tests that need to be carried out.

Making a DNA fingerprint



11.9.2 Cutting and pasting DNA

DNA can be manipulated in different ways using **recombinant DNA technology**. Sections of DNA can be cut using specific enzymes and the 'desirable' genes of a species inserted into the DNA of the same or another species. Plant genes can be inserted into animal cells and animal genes into plant cells. A plant, animal or other kind of organism with a foreign gene is known as **transgenic**. The foreign gene will behave in the same way as it would in its own species. For example, the addition of a gene from phosphorescent jellyfish to a mouse results in the mouse being phosphorescent.

Busy bacteria and insulin

Before developments in gene technology, people who had diabetes had to use insulin extracted from the pancreas of pigs. Immune reactions sometimes occurred. Now the human gene that codes for the production of insulin is inserted into the plasmids, rings of DNA, of bacteria.

The transgenic bacteria and their plasmids divide rapidly when cultured in large vats and produce large quantities of insulin.

The plant invader

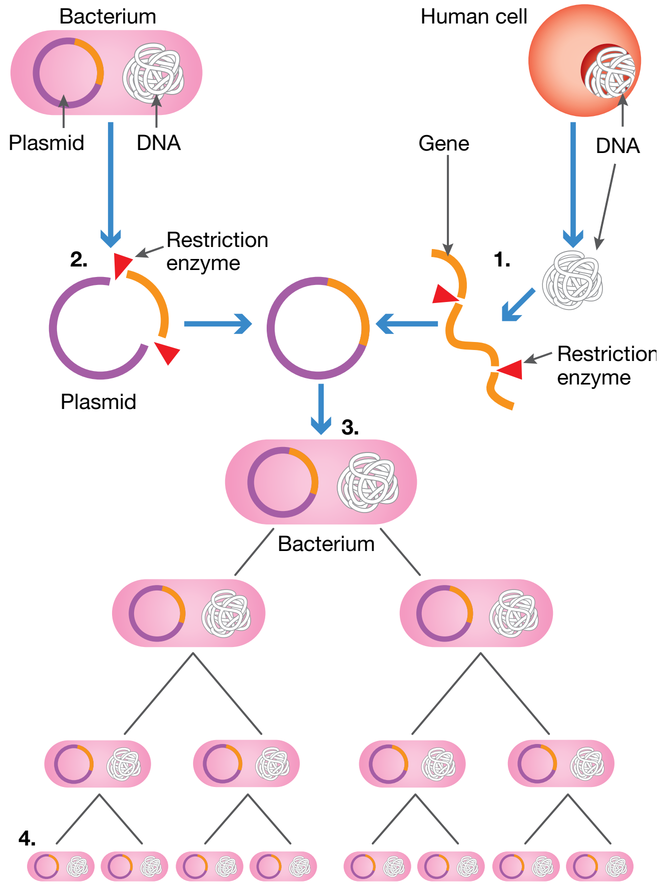
Agrobacterium tumefaciens is a soil bacterium. It is able to get inside and infect many plants such as vines and fruit trees. In doing so, it transfers a tiny piece of its DNA into the host cell. This programs the host cell to make chemical compounds for the sneaky bacterium to feed on. Genetic engineers saw the possibility of using this bacterium as a **vector** to carry the genes they wanted from one plant into another.

Other kinds of bacteria and viruses act as vectors and carry genetic information from one organism (or synthesised to be like that organism) to another organism. Vectors can be used to carry genes for producing protein in soybean and sunflower plants, manufacturing enzymes to control chemical processes, and producing compounds that keep insects or pathogenic viruses at bay.

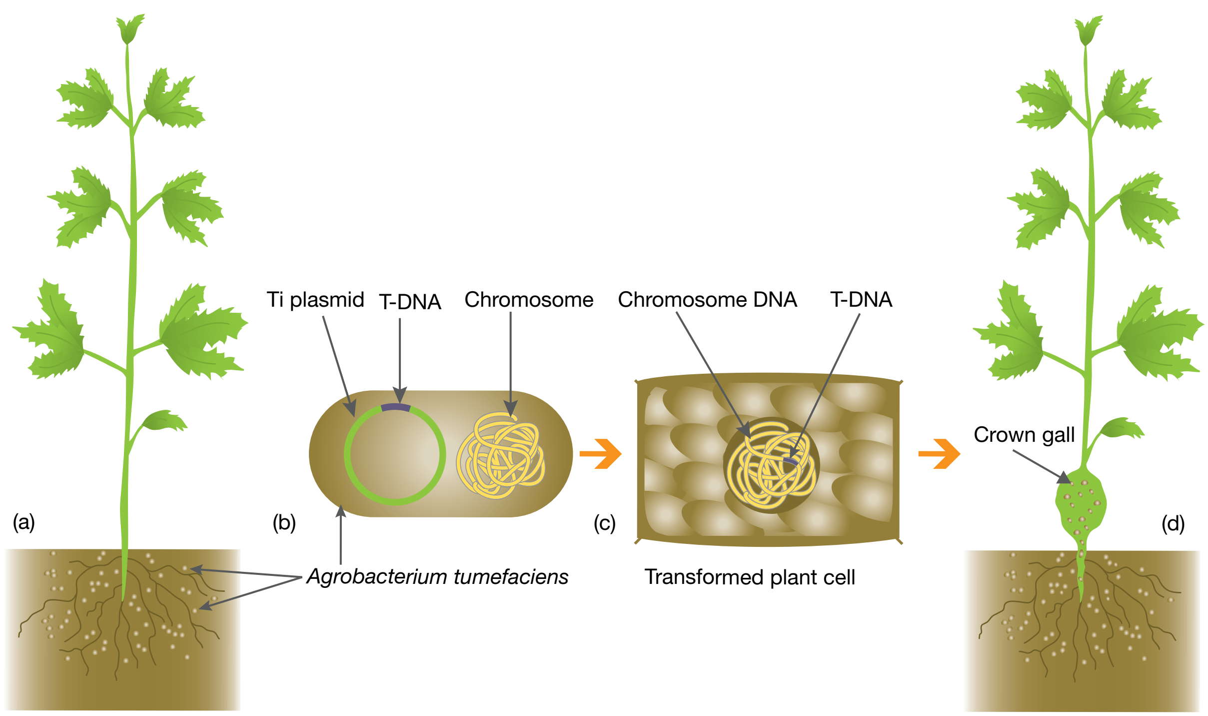
Take aim . . . fire!

Recent developments have enabled foreign genes to be inserted into plant tissues by shooting them in with gas guns! Fine particles of gold are coated

Bacteria can produce human insulin if the insulin gene is inserted into the bacterial cells.

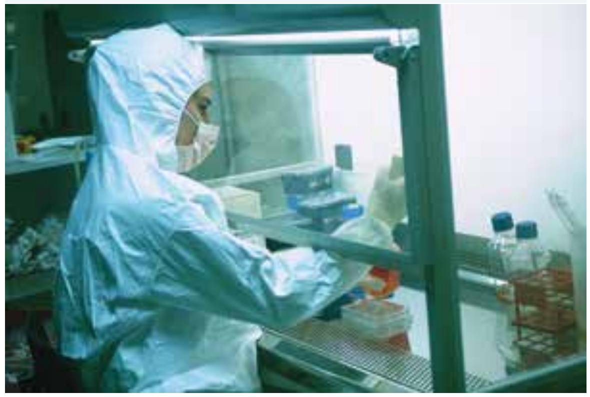


When the bacteria *Agrobacterium tumefaciens* infects a plant it inserts some of its DNA into the DNA of the plant. Geneticists have used this bacterium to insert genes into plant DNA.



with the DNA and shot into the cells. Some cells are killed in the process but some survive, carry out mitosis and may develop into complete plants with an altered genotype. Many plant crops such as maize and soybean have had 'favourable' genes added to them in this way.

A medical research laboratory.



Biotechnology involving gene technology is a rapidly expanding branch of science. Already there have been trials of viral-vector nasal sprays to help treat cystic fibrosis sufferers with limited success. Some of the viruses carried by these vectors penetrate cells lining the respiratory tract and insert the 'normal' gene into those cells. Vaccines against a number of diseases in humans and other animals are being investigated. Biotechnologists are trying to genetically engineer bananas to produce a vaccine against the hepatitis B virus. Will genetically engineered vaccines eventually treat diseases such as AIDS?

Should or shouldn't we?

Is transferring genes wise use of technology? Some people argue that not enough is known about the way genes can 'jump' the species barrier. Maybe they will end up where they shouldn't, or they may cause problems higher up the food chain. What could be the effect on other species in the environment? Could 'foreign' genes interact with host genes and cause problems? Could viral vectors and genes mutate so that they would infect not only the target species but others too?

HOW ABOUT THAT!

Transgenic salmon

A lot of the salmon we eat is farmed salmon. The salmon grows in large tanks until it reaches a certain size and is harvested. For salmon farmers there would be great financial benefits if salmon could grow faster. A company called AquAdvantage has achieved just that. They have added two genes to Atlantic salmon: one from another type of salmon that controls growth hormone production and one from an eel-like fish that allow the salmon to survive in near freezing water. The resulting salmon grows much faster than it otherwise would. In the US the FDA recently granted approval for the sale of the transgenic salmon. Extensive testing was carried out before FDA approval was granted but in the mind of many consumers doubt remains about the safety of the genetically modified fish.

11.9 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

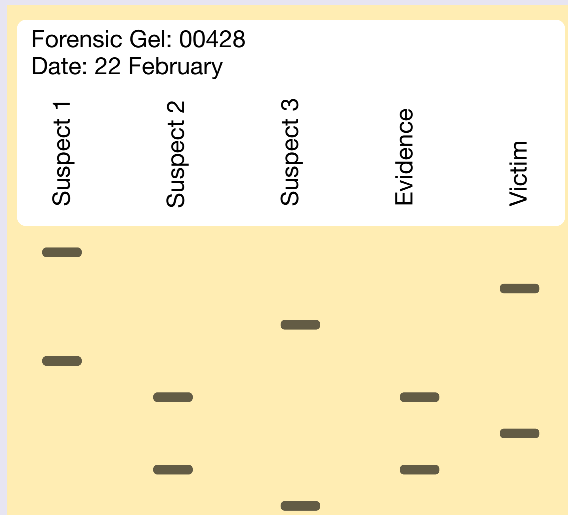
1. Match the following words with their meanings.

Words	Meanings
(a) Transgenic	(i) A pattern of bands obtained when electrophoresis is carried out on a sample of DNA that has been cut using restriction enzymes
(b) Host cell	(ii) A technique used to separate fragments of DNA of different lengths
(c) Plasmid	(iii) Cutting and pasting DNA from one species to another
(d) *Agrobacterium tumefaciens*	(iv) A test that determines if a man is the father of a child by comparing the DNA fingerprint of the man and child

Words	Meanings
(e) DNA fingerprint	(v) A cell that has been infected by a bacteria or virus
(f) Electrophoresis	(vi) A bacterium that infects plants, and can be used to insert genes into the DNA of other plants
(g) Paternity test	(vii) A ring of DNA found in bacteria
(h) Recombinant DNA technology	(viii) Organisms that contain foreign genes

2. Copy and complete the sentences below using words from the list given.
   bands; DNA; gene; electrophoresis; human; enzymes; fingerprint; plasmids
   (a) To create a DNA __________ you need to obtain a sample of DNA and cut it at particular locations using __________ . __________ is then used to separate the pieces of DNA and a pattern of __________ is obtained.
   (b) We can make bacteria produce human insulin by cutting out the __________ responsible for insulin production from a sample of __________ DNA.
   (c) This __________ is then inserted into the __________ of the bacteria. When the bacteria reproduce they replicate the __________ containing the insulin producing __________.
3. **Describe** some applications or uses of DNA fingerprinting.
4. **Outline** some methods used to transfer 'foreign' genes into other organisms.

Think



5. The diagram at right shows the DNA fingerprints produced from specimens collected from three crime suspects, the victim and evidence collected on the victim's body.
   (a) Using the information in the DNA fingerprints, **deduce** which of the three suspects is most likely guilty of the crime against the victim.
   (b) **Explain** your response to part (a).
   (c) **Justify** why a sample was taken from the victim as well as the foreign DNA sample collected from her body.
6. **Discuss** the following statement:
   'We should have a database that stores the DNA fingerprint of all people living in Australia. This would make catching criminals much easier.'
7. **Explain** why the uses of recombinant DNA technology listed below can have benefits for society:
   (a) inserting the human insulin gene into bacteria
   (b) inserting a gene that makes cotton plants produce a chemical that kills insect pests
   (c) inserting a gene for growth hormone in salmon (this makes the salmon grow larger)
   (d) inserting a gene that makes bananas produce a vaccine for hepatitis B
   (e) inserting a gene that makes rice very high in vitamin A (vitamin A deficiency is a cause of blindness in poor countries).
8. Some canola, soybean, maize and cotton varieties have been genetically engineered to make them resistant to the weed killer glyphosate. They also produce a higher crop yield.
   (a) **Explain** why growing a crop that is resistant to glyphosate makes weed control a lot easier for farmers.
   (b) **Discuss** whether this use of genetic engineering is beneficial to the rest of society.
   (c) The company that developed these varieties of crops also sells glyphosate. **Explain** how the company benefits from this type of genetic engineering.
   (d) Farmers in poorer countries cannot afford to buy genetically engineered seeds or glyphosate. Rather than buying seeds each growing season, they often keep some seeds produced by the previous year's crop and weeds are removed by hand. **Explain** how the genetically engineered crops grown by farmers in wealthy countries might make it more difficult for farmers in poorer countries to make money.

(e) There is concern that genetically engineered plants might cross with wild species of plants and that the foreign genes could spread to weeds. **Assess** the impact of this.

9. Genetically modified (GM) foods are foods that contain genes from other species, such as tomatoes that contain a gene from fish. **Account for** the fact that people who have allergies may have concerns about GM foods.
10. **Assess** whether it should be compulsory for products containing genetically modified ingredients to be labelled as such.

Investigate

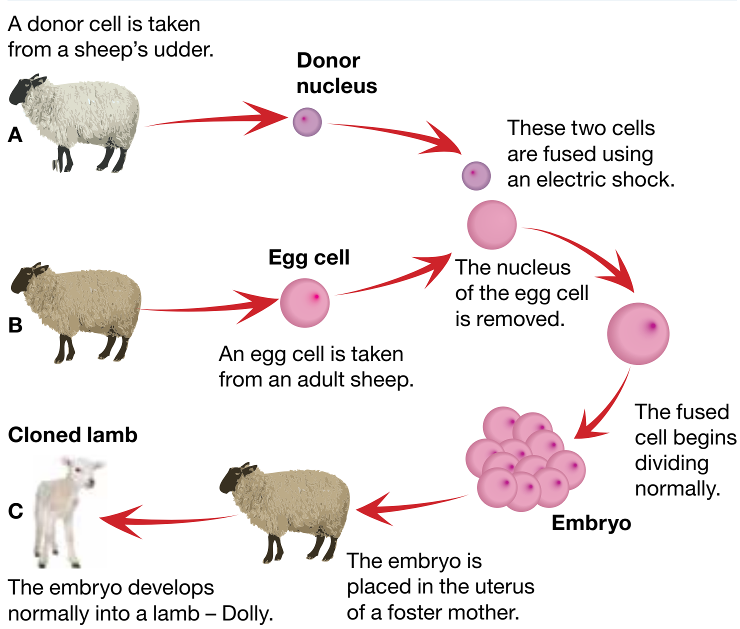
11. In a group, compile a folio of about ten journal and other media articles relating to gene technology. Note the date and source of each article. Each person will choose an article to analyse. In your analysis include:
    (a) the kind of gene technology being reported on
    (b) a simple description or explanation of the particular example of technology
    (c) any issues relating to the example.
12. In 1993, American scientist Kary Mullis won the Nobel Prize in Chemistry for investigating PCR. Find out more about the discovery and applications of PCR.
13. Suggest implications of patenting any of the following:
    (a) genes
    (b) gene products
    (c) specific drugs that target a gene or gene products.
14. Various countries and organisations are already developing DNA databases.
    (a) What is a DNA database?
    (b) Use a PMI chart to categorise possible applications of DNA databases.
    (c) Provide your own personal opinion on DNA databases. Include reasons for your opinion.
15. Research one of the following Australian research institutes and find out more about their genetic research.
    (a) Ludwig Institute for Cancer Research
    (b) Howard Florey Institute of Experimental Physiology and Medicine
    (c) Walter and Eliza Hall Institute
16. What is thalassaemia? Find out more about screening and diagnostic tests for this genetic disorder. Find out more about the Thalassaemia Society and its involvement in genetic counselling.

11.10 Send in the clones

11.10.1 Clones

Clones are organisms that are genetically identical. Identical twins are natural clones and so are plants grown from cuttings or using any other type of asexual reproduction. In 1997, Dolly the sheep, the first artificial mammal clone, was born. Since then many other mammals have been cloned, so the technology that would allow us to produce artificial human clones is available. Should scientists be allowed to clone humans?

How Dolly the sheep was created



11.10.2 Nuclear transfer cloning

Nuclear transfer cloning is used to produce organisms that are genetically identical to a fully developed organism.

If nuclear transfer cloning involving humans was carried out it could produce a baby that would be genetically identical to her mother, or a baby genetically identical to an older sister. A beloved pet could be replaced by its clone provided that a sample of cells was collected from the animal soon after death. It may even be possible to clone extinct organisms if a well-preserved sample of DNA was available.

Nuclear transfer involves the following steps:

1. Extract DNA from a body cell (not an egg) from animal A.
2. Obtain an egg cell from another animal (or the same animal) and remove the DNA from the egg cell. Insert the DNA from animal A into the egg.
3. Implant the egg (containing the DNA from animal A) into the womb of an animal. Allow the egg to divide and develop inside the womb.

When the animal is born it will be genetically identical to animal A.

In 1970, John Gurdon successfully cloned a frog and it grew as far as the tadpole stage. In 1997, Ian Wilmut and colleagues produced Dolly, the cloned sheep (after 277 attempts). Since the cloning of Dolly, many mammals have been cloned by different laboratories around the world. It has been noticed that some cloned animals suffer from disorders and they often die young.

The world's first cloned cat, CC (Carbon Copy), born December 2001

The world's first cloned dog, an Afghan called Snuppy, born April 2005 after 1095 attempts

11.10.3 Therapeutic cloning

In **therapeutic cloning** the purpose of cloning is different. The aim is not to produce a fully functional organism, but rather to produce cells that might be used for research or to produce organs for transplant.

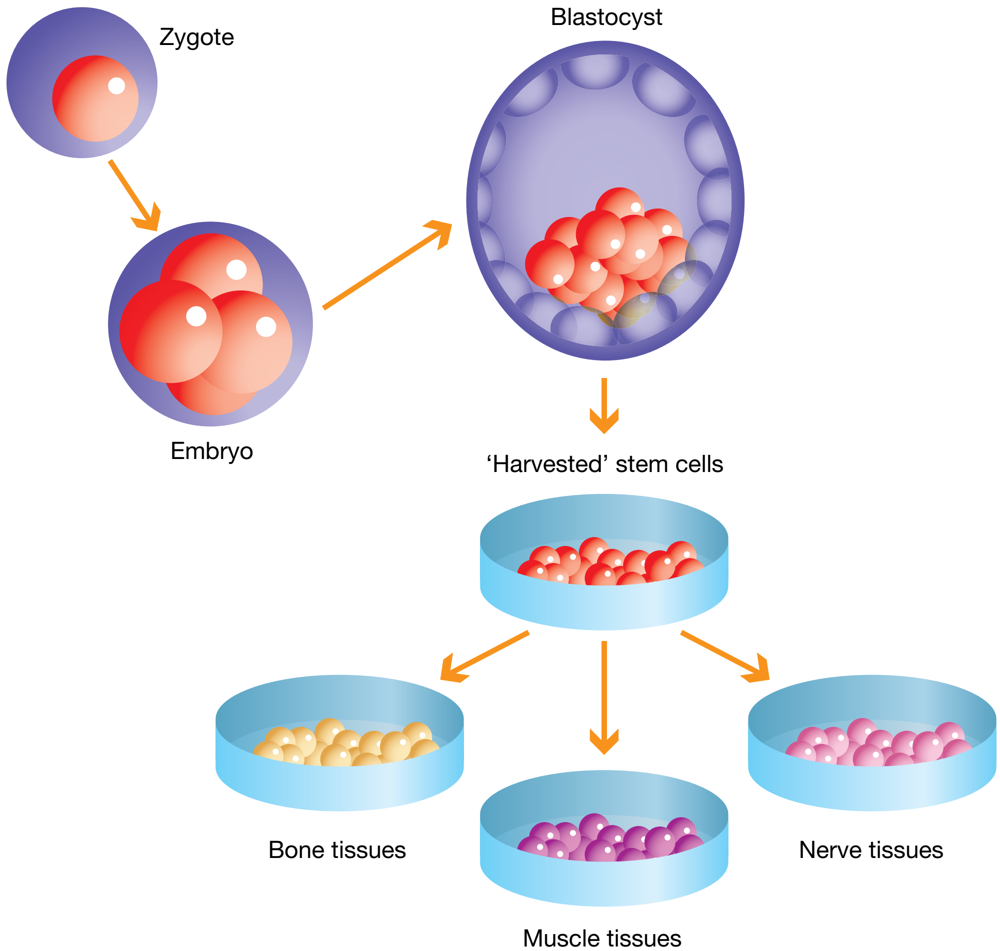
Therapeutic cloning involves initially the same steps as nuclear transfer cloning:

1. The DNA from an egg cell is removed and replaced with the DNA of a normal body cell.
2. The egg cell is then allowed to divide and form into an embryo. The embryo is not implanted into the womb of an animal, however.
3. Some of the cells that make up the embryo are stem cells. Stem cells can develop into various types of tissue depending on the conditions under which they grow. The stem cells are collected and may be used for scientific research or other purposes such as growing new organs.

It may one day be possible to grow organs for transplant using this technology. Furthermore, if the stem cells were produced using the patient's own cells, the organ would be a perfect genetic match and would not be rejected.

While this approach has not yet led to the successful treatment of any condition, research scientists have produced nerve cells, insulin-producing cells and others, which could one day be used to treat diseases including Parkinson's disease, Alzheimer's and diabetes.

Therapeutic cloning can be used to produce stem cells.



11.10.4 Ethical implications

Genetically, humans are not very different from sheep, cats or dogs. These animals have been successfully cloned, so it should be possible to clone humans. Currently in Australia it is illegal to produce human babies using nuclear transfer cloning technology. In 2006, therapeutic cloning (for the purpose of producing stem cells) was made legal. It is also legal to use surplus embryos produced by IVF for stem cell research, provided that the parents agree to this. Reproductive cloning (for the purpose of making babies) remains illegal. Much debate preceded the passing of this Bill. The debate centred around the following issues:

- What are the potential benefits of this technology?
- When does life begin? Is a fertilised egg a human life? Is an embryo produced by therapeutic cloning a life?
- Do the embryos used in this type of research have the potential to become fully developed humans?
- In the case of surplus embryos produced by IVF, what would happen to these embryos if they were not used for stem cell research? Would they be destroyed anyway?

The views of the ministers involved in this debate were sometimes shaped to some extent by their religious beliefs. It should also be noted that state laws can overrule the Bill that was passed in 2006, so individual states can ban therapeutic cloning and the use of surplus embryos for research.

How do you feel about cloning? Should therapeutic cloning be legal? Are there any situations where the production of babies by cloning should be legal?

11.10 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Match the words below with their meaning.

Word	Meaning
(a) Clone	(i) Cells that can develop into a range of different tissue
(b) Denucleated	(ii) When an embryo is produced by replacing the DNA of an egg cell with the DNA of a normal body cell
(c) Nuclear transfer cloning	(iii) Genetically identical organisms
(d) Therapeutic cloning	(iv) A bunch of cells produced from a fertilised egg (or from an egg cell that has had its DNA replaced with the DNA of a normal body cell)
(e) Stem cells	(v) Cloning for the purpose of producing cells for research or to make tissues or organs rather than entire organisms
(f) Embryo	(vi) Has had its nucleus removed

2. Study the figure How Dolly the sheep was created in this subtopic. In the diagram, **identify** which sheep is (i) the egg donor (ii) the surrogate (iii) the sheep that the lamb is genetically identical to.

Think

3. Did Dolly the sheep have any genetic material from a ram?
4. **Outline** some reasons why:
   (a) a horse breeder may wish to clone one of her horses
   (b) a couple may ask scientists to try to produce a clone of one of their children.
5. **Discuss** whether the following should be legal in Australia:
   (a) human cloning
   (b) animal cloning
   (c) therapeutic cloning (using human cells).

Investigate

6. Dolly lived only to the age of six before being put down due to ill-health. Other cloned animals have also experienced ill-health and a short life span. Research this phenomenon.
   (a) How much evidence is there that these clones had ill-health because they were clones?
   (b) What theories are there as to why cloning may cause illness and abnormalities?
   (c) If cloning does often cause health problems, does this mean it should not be undertaken?
7. Use the **Religious views on cloning** weblink in the Resources tab to answer the following questions:
   (a) Which religions have the most favourable views towards cloning? **Explain** why.
   (b) Which religions are most against cloning? **Explain** why.
8. Use the **Click and clone** weblink in the Resources tab to learn more about cloning.

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Explore more with this weblink: Religious views on cloning

Explore more with this weblink: Click and clone

11.11 Project: The gene lab

11.11.1 Scenario

Think of how different dog breeds such as chihuahuas, great danes, dachshunds, blue cattle dogs and dobermans are from each other. Yet all of our pet dog breeds — regardless of size, colour, coat and intelligence — are all still members of the same species. All dogs are descended from a long-gone species of wolf. Over the thousands of years that they have been mankind's companions, we have selectively bred dogs together so that particular characteristics became more pronounced while others faded out. For example, greyhounds with their long graceful legs were bred for speed while bullmastiffs were bred for their size and strength. Over time, these characteristics became fixed in that breed. The breeding process is continuous, with new breeds being registered with the International Federation of Dog Breeders every few years.

Dog breeders try to produce dogs that are the ideal examples of their breed, and do so by carefully selecting which dogs to mate. Unfortunately, in their quest to establish these perfect examples, the dogs produced may inherit genetic disorders as a result of unfortunate genetic combinations or inbreeding. Purebred labradors, for example, may develop hip dysplasia, knee problems and eye problems such as progressive retinal atrophy which — as well as preventing the dog from being shown in competitions — have serious effects on the dog's quality and length of life. Now that genetics and DNA are more fully understood, it is not uncommon for dog breeders to consult with genetic scientists to ensure that the puppies they produce have the smallest risk of developing these disorders.

11.11.2 Your task

You are part of a team of vets that works for the Dog Breeders Association of Australia as genetic counsellors. Your client has a labrador bitch that has a family history of progressive retinal atrophy — a condition that causes gradual blindness. The client would like to breed her to produce for show as many puppies as possible that do not carry the gene for the disorder. There are three available stud dogs that the bitch can be mated with. Given the pedigree of each of these dogs, you must determine which of them should be selected to sire the litter. You will give your recommendations to the client in the form of a genetic report explaining your decision — including family trees, phenotype and genotype identification, and final breeding recommendations.

11.11.3 Process

- Start your research. Make notes of how recessive and dominant genes are combined when two animals mate to produce offspring, as well as how pedigrees are used to predict their genetic make-up. Each team member should use at least three sources other than the textbook, and at least one offline source (such as a book or encyclopaedia) to help discover extra information about genetics and dog breeding.
- Based on your research notes and the report template, complete each of the required sections of your report.

11.12 Review

11.12.1 Genes and chromosomes

- **define** the terms 'gene', 'trait', 'chromosome' and 'karyotype' **11.2**
- **outline** how genes control characteristics **11.2**
- **contrast** the karyotypes of human males and females **11.2**
- **identify** some human characteristics that are genetically determined **11.5**

11.12.2 Cell division and fertilisation

- **compare** the processes of meiosis and mitosis **11.3**
- **explain** how the sex of a baby is determined at fertilisation **11.3**

11.12.3 The nature and practice of science

- **assess** the experimental procedures used by Gregor Mendel for his pea breeding experiment **11.4**
- **predict** the outcome of genetic crosses using punnett squares **11.4**

11.12.4 DNA

- **describe** the structure of DNA **11.6**
- **outline** the process of DNA replication **11.6**
- **explain** the advantages of DNA replicating exactly **11.6**

11.12.5 Mutations

- **define** the terms 'mutation', 'mutagen' and 'tumour' **11.7**
- **explain** how mutations may be detrimental to an organism **11.7**
- **identify** examples of mutations that may be beneficial to an organism **11.7**

11.12.6 The role of genes and environment in determining features

- **define** the terms 'dominant', 'recessive', 'heterozygous' and 'homozygous' **11.8**
- **classify** factors that are important in determining the features of an organism as either genetic or environmental **11.8**
- **describe** examples that illustrate the role of environmental factors in determining the features of an organism **11.8**
- **interpret** pedigree diagrams **11.8**

11.12.7 Current issues, research and developments

- **identify** careers that require an understanding of genetic principles **11.8**

11.12.8 Implications of science for society and the environment

- **identify** applications of DNA fingerprinting 11.9
- **outline** the procedure used to create transgenic species and some applications of this technology 11.9
- **contrast** reproductive, nuclear transfer and therapeutic cloning 11.10
- **outline** how artificial mammal clones can be produced 11.10
- **discuss** using examples, the positive and negative impacts of gene technology and cloning 11.10
- **explain** why different groups in society may have different views about gene technology wand cloning 11.10

Individual pathways

ACTIVITY 11.1	ACTIVITY 11.2	ACTIVITY 11.3
Revising genetics doc-10671	Investigating genetics doc-10672	Investigating genetics further doc-10673

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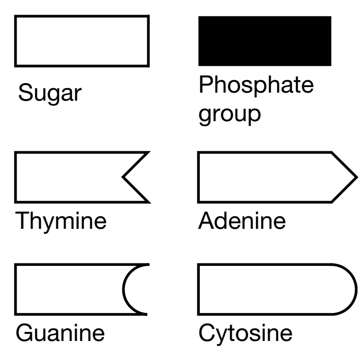
FOCUS ACTIVITY

(a) **Construct** a paper model of DNA. Some suggested shapes you could use to represent the parts that make up a DNA molecule are shown at right.
(b) Now construct a second model that shows the DNA you made in part A replicating.
(c) **Evaluate** the models. Which aspects of the structure of DNA does your model show accurately? In what ways is your model different to an actual DNA molecule? What aspects of DNA replication are not shown clearly in your model?
(d) Computer animations are another type of model. **Outline** some advantages and disadvantages of making a paper model rather than using a computer animation to learn about DNA replication.

Access more details about focus activities for this topic in the Resources tab (doc-10670).



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11.12 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

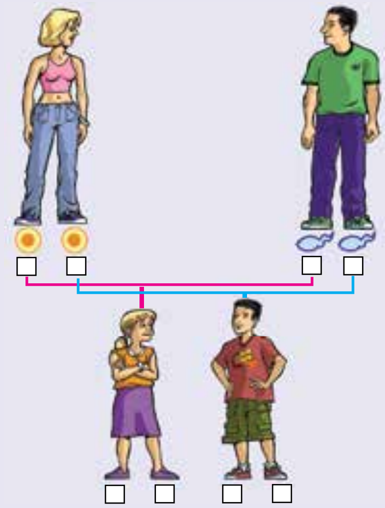
Remember

1. Match the following terms with the correct definition.

Terms	Definitions
(a) DNA	(i) An image of a full set of chromosomes after they have been stained, arranged in pairs and labelled
(b) Gene	(ii) Containing one copy of each chromosome
(c) Allele	(iii) A very long piece of DNA containing many genes and with associated proteins
(d) Chromosome	(iv) Containing two copies of each chromosome

Terms	Definitions
(e) Karyotype	(v) Deoxyribonucleic acid, a large molecule that codes genetic information
(f) Haploid	(vi) A length of DNA that contains instructions for one polypeptide
(g) Diploid	(vii) A variant form of a gene

2. Arrange the sentence fragments below to complete the sentence that has been started for you.
is made up of
cells
DNA
which contain in the nucleus
which are made up of
chromosomes
which contain
genes
A living organism ______________________________.

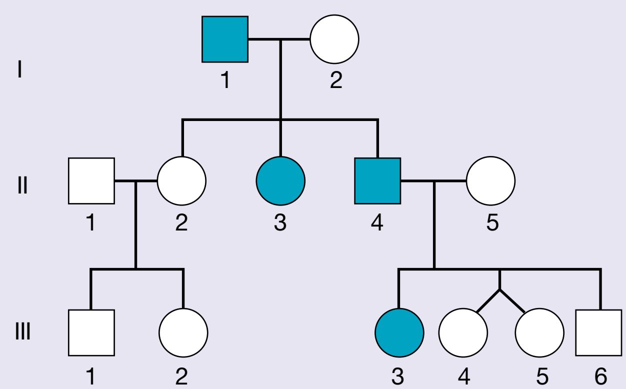


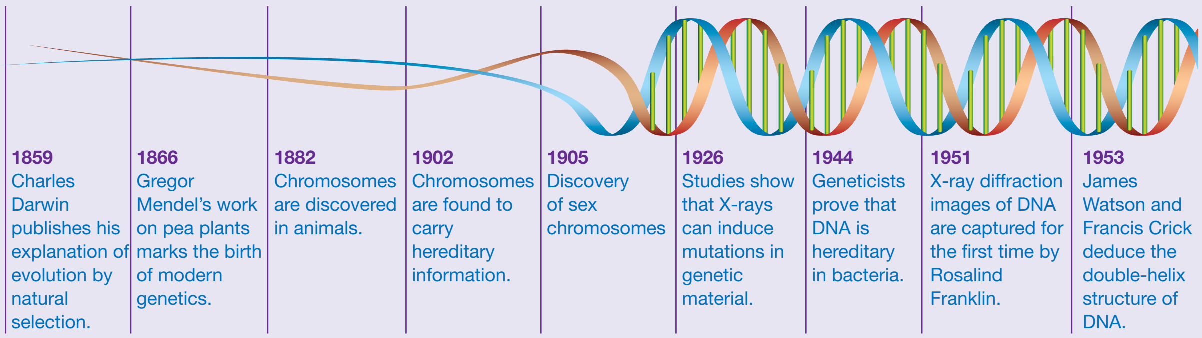
3. Suggest the missing sex chromosome labels for the figure at right.
4. **Outline** some of the roles that proteins play within living organisms.
5. **Describe** the structure of DNA with the aid of a diagram.
6. Use the timeline along the top of the next pages to answer the following questions.
   (a) When were chromosomes first discovered in animal cells?
   (b) How many years after Gregor Mendel's work on pea plants was the structure of DNA discovered?
   (c) How many years did it take scientists to complete the first draft of the Human Genome Project?
   (d) Write down two further milestones that could be added to the timeline after 2003.
7. **Explain** how a change in DNA sequence is the cause of the condition sickle-cell anaemia.
8. For each of the following, decide whether mitosis or meiosis is being described:
   (a) used for growth and development
   (b) results in haploid cells
   (c) increases the variation in offspring
   (d) results in two cells with the same genetic content as the parent cell
   (e) involves two rounds of cell division.
9. Decide whether the following are true or false. Correct any false statements.
   (a) A dominant trait shows up in every generation.
   (b) The phenotype is the genetic make-up of an organism.
   (c) A heterozygote has two copies of the same allele.
   (d) The environment has an effect on the genotype of an individual.
10. The pedigree chart at right shows the inheritance pattern of Huntington's disease. This disease is due to a dominant HD gene on chromosome 4.
   (a) How many generations are shown?
   (b) How many females are in the pedigree?
   (c) How many males are in the second generation?
   (d) **Identify** three individuals who have Huntington's disease.
   (e) If *'H'* represents the allele for Huntington's disease, **Deduce** the genotypes of:
      (i) individuals 1 and 2 in the first generation
      (ii) individuals 2 and 4 in the second generation.
   (f) How would the pattern in the pedigree be different for a recessively inherited trait?

Pedigree chart showing the inheritance pattern of Huntington's disease

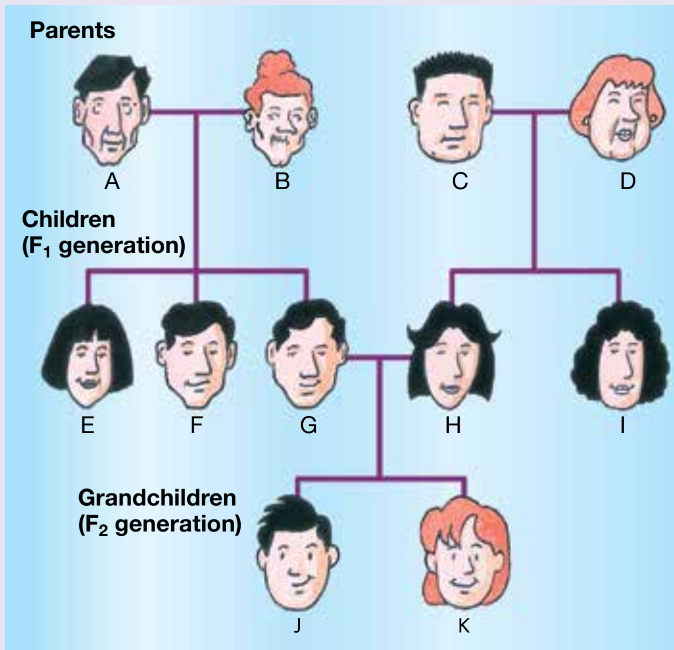
Key

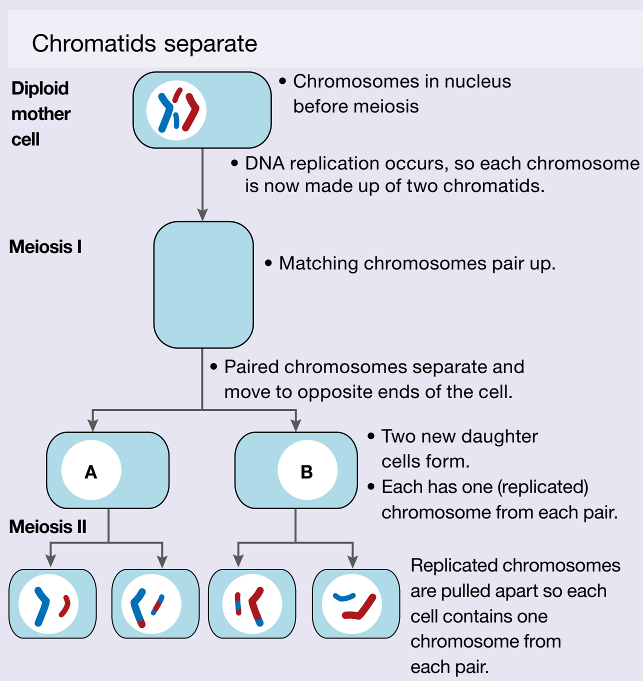
□	Normal male	●	Affected female
■	Affected male	○	Normal female
	Identical twin	1, 2, 3, etc.	Sequence of individuals





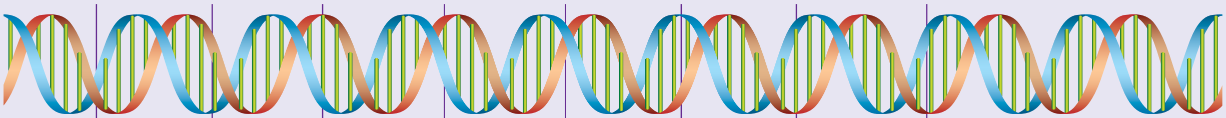
11. Using the letters *'B'* or *'b'* to represent the gene for coat colour, **predict** the results of the following crosses. Draw diagrams or punnett squares to show your predictions.
    (a) A pure-breeding (homozygous) black mouse with a hybrid (heterozygous) black mouse
    (b) A pure-breeding black mouse with a pure-breeding white mouse.
    Is black dominant to white or white to black? Support your answer.
12. **Examine** the pedigree chart at right. Let the dark hair allele be represented by *B* and the red hair allele by *b*.
    (a) **Deduce** the genotypes for the individuals: B, G, H and K.
    (b) **Deduce** the phenotypes for individuals F and D.
    (c) If individuals G and H had another child, what is the chance that it would have red hair?
    (d) If individuals F and I had a child, do you think it might be possible for it to have red hair? **Explain** your reasoning.
13. In your book draw the pictures that belong where the letters A and B appear in the diagram at right.





Test yourself

1. Which of the statements below is correct?
   (A) All human cells contain 23 chromosomes.
   (B) Egg and sperm cells contain 46 chromosomes.
   (C) Females have one more chromosome than males.
   (D) A zygote contains 46 chromosomes. **(1 mark)**
2. The type of cell division that produces cells with half the number of cells of the original cell is called
   (A) binary fission.
   (B) mitosis.
   (C) recombinant DNA technology.
   (D) meiosis. **(1 mark)**



1973 DNA splicing heralds dawn of genetic engineering.

1978 Genetically modified bacteria produce the hormone insulin.

1986 Researchers produce millions of copies of DNA in a few hours.

1990 Human genome project begins. Gene therapy successful for the first time.

1994 Genetically modified tomatoes go on sale in US.

2000 Completion of draft human genome

2003 First genetically modified pet fish goes on sale. Human genome project completed.

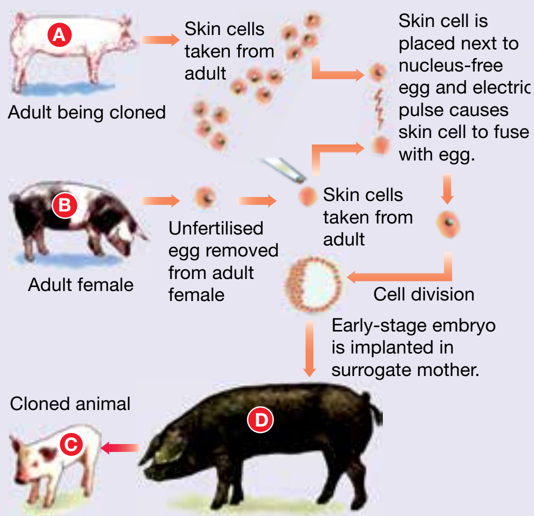
Future Gardeners and pet breeders use genetic engineering kits to create new varieties. Biotechnology games for kids launched. New plants and animals bred to live on Mars.

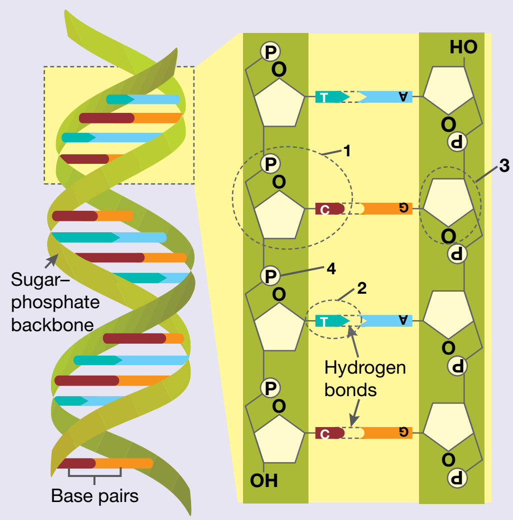
3. A diagram representing a DNA molecule is shown below right. Which row in the table below shows the correct names for the structures labelled with the numbers 1–4 in the diagram?

	Part 1	Part 2	Part 3	Part 4
A	Nucleotide	Nitrogenous base	Phosphate group	Sugar
B	Chromosome	Nucleotide	Adenine	Cytosine
C	Nitrogenous base	Sugar	Phosphate group	Polypeptide
D	Nucleotide	Nitrogenous base	Sugar	Phosphate group

(1 mark)

4. A diagram is shown below.





Which of the statements below is correct?

(A) Pig A and pig C are genetically identical.
(B) Pig D and pig C are genetically identical.
(C) Pig B is the surrogate mother of pig C.
(D) None of the pigs are genetically identical as the environment in which the pigs grow can affect their genotype. **(1 mark)**

5. **Discuss** the impact on society of one the following biotechnologies: DNA fingerprinting, cloning, recombinant DNA technology. **(1 mark)**

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Complete this digital doc: Worksheet 11.8: Genetics puzzle (doc-12813)

Complete this digital doc: Worksheet 11.9: Genetics summary (doc-12814)

TOPIC 12 Life goes on

12.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

12.1.1 Why learn this?

Fossils show us that life on Earth has changed over time. Some species such as the dinosaur shown in this picture have become extinct. New species have arisen as well. Evolution has occurred. How has this happened? What is the mechanism through which the process of evolution takes place?

LEARNING SEQUENCE

Fossils are evidence of past life.

From the days of the dinosaurs

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

In 1938, a South African museum curator, Marjorie Courtenay-Latimer, pulled a strange blue fish from a fisherman's catch. It was a coelacanth, previously only known from fossils aged between 80 and 360 million years old. In 1997, another species was found living in deep waters off the coast of Indonesia.

In 1994, National Parks officer David Noble was out bushwalking when he stumbled across a strange tree deep in the Blue Mountains, New South Wales. It looked like nothing alive today, but similar to the 200 million year old *Araucariaceae* family. It was described as '. . . the equivalent of finding a small dinosaur'. There are only about 100 Wollemi pines alive in their protected natural location. To ensure the survival of this rarest of tree species, Wollemi pines are being cultivated for sale through nurseries.

A coelacanth

Thinking about fossils

1. Study the picture of the coelacanth. Do you notice anything unusual about the fins of this fish?
2. The coelacanth is a lobe-fin fish. Find out what that means.
3. Look at the pictures of the Wollemi pine. Compare the Wollemi tree to other conifers such as pine trees.
4. The coelacanth and the Wollemi tree have both been called 'living fossils'. Explain why.
5. A habitat is a place where an organism lives and obtains its food, water, shelter and any other requirements for survival. What might the habitats of these 'living fossils' have in common?
6. Why do you think these species have survived unchanged for millions of years when others haven't?
7. (A) What threats could modern society pose to the survival of these rare species?
   (B) How could these threats be minimised?

A Wollemi pine

Five minutes to midnight

If we compressed the Earth's 4.5 billion year history into a single year, Earth would have formed on January 1 and the present time would be represented by the stroke of midnight on 31 December. Using this time scale, the first primitive microbial life forms appeared in late March, followed by more complex photosynthetic micro-organisms towards the end of May. Land plants and animals emerged from the seas in mid-November. Dinosaurs arrived early on the morning of 13 December and then disappeared forever in the evening of 25 December. Although human-like creatures appeared in Africa during the evening of 31 December, it was not until about five minutes before the New Year that our species, *Homo sapiens* appeared on Earth.

1. Four-and-a-half billion years is a very long time. What is the advantage of compressing all the Earth's history into a single year?
2. What important message about Earth's history does the paragraph above tell you?

Male cone of a Wollemi pine

12.2 Life has changed

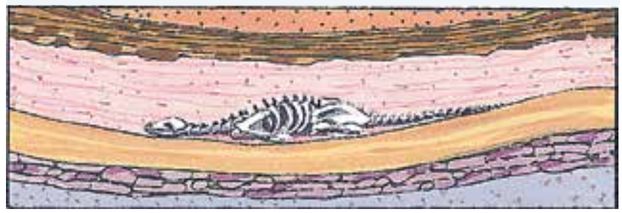
12.2.1 The fossil record

Fossils provide evidence that life has changed over time. Life forms that used to exist on Earth no longer exist. Studying the fossil record also provides evidence that life forms have become more complex over time.

A **fossil** is evidence of past life. Fossils can be parts of an organism, such as its bones, teeth, feathers, scales, branches or leaves. Usually when an organism dies, micro-organisms cause so much decay that eventually no part of it remains. However, if an organism is covered shortly after its death by dirt, mud, silt or lava (as can happen, for example, if it becomes trapped in a mudslide or in the silt at the bottom of the ocean), the micro-organisms that cause the decay cannot work. This is because there is no oxygen. Over millions of years, the material covering the dead organism is compressed and turned into rock, preserving the fossil within it.

1. A dinosaur dies and is quickly covered by sediment

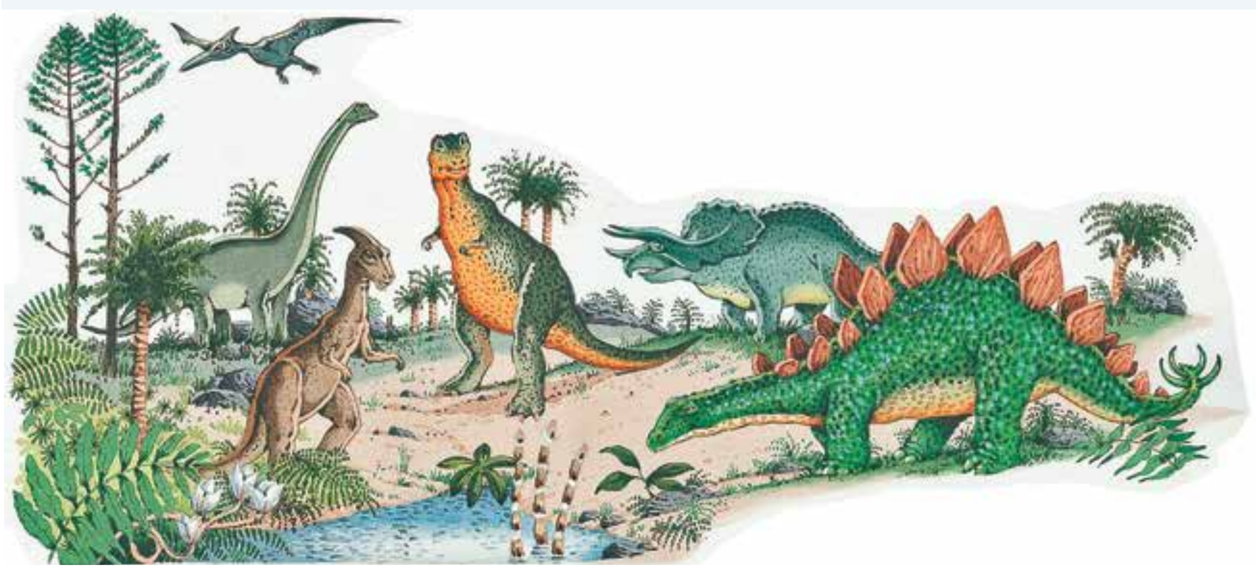
2. Over time, the sediment turns into rock. The remains of the dinosaur turn into a fossil.



3. The fossil is flattened by the layers of rock.

4. The rock is folded and eroded and the fossil can be seen on the surface

The fossil record indicates that huge reptiles used to roam the Earth.



Fossils can also be footprints, burrows and other evidence that an organism existed in the area. For example, a dinosaur track has been discovered in the Otway Range in southern Victoria. By observing the footprints in the track, **palaeontologists**, who study fossils, can work out the size, weight and speed of the dinosaur that made them.

12.2.2 Types of fossils

Examples of fossils include moulds, casts, imprints, petrified organisms, as well as whole organisms that have been preserved by being frozen or trapped in amber.

Cast — a rock with the shape of an organism protruding (sticking out) from it

Carbon imprint — the dark print of an organism that can be seen on a rock

Whole organism — larger organisms that have been preserved whole by being mummified or frozen, such as this baby mammoth found in 2007 in Siberia

Mould — a rock that has an impression (hollow) of an organism

Amber fossils — parts of plants, insects or other small animals that have been trapped in a clear substance called amber

Petrified fossil — organic material of living things that has been replaced by minerals. The photograph below shows petrified wood.

INVESTIGATION 12.1

Studying fossils

AIM: To investigate the different types of fossil (cast, mould, imprint or other)

You will need:

fossils, fossil casts or pictures of fossils

Copy and complete the table below for each type of fossil.

Name	Description	Type of fossil (cast, mould, imprint or other)

12.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Match the words in the table below with their meanings.

Words	Meanings
(a) Fossil	(i) Organisms trapped in this substance may be preserved.
(b) Palaeontologist	(ii) A black print left behind after the organism decomposes
(c) Sedimentary	(iii) Evidence of past life
(d) Carbon imprint	(iv) Scientist who studies fossils
(e) Amber	(v) The type of rock where fossils may be found

2. Copy and complete the following statements using these words: amber, bacteria, covered, decay, droppings, evidence, footprints, fossilise, minerals, partial, petrified remains.
   (a) Fossils are ______________ of past life. They may include preserved or fossilised ______________ or an entire organism, as well as _______________ and fossilised _______________.

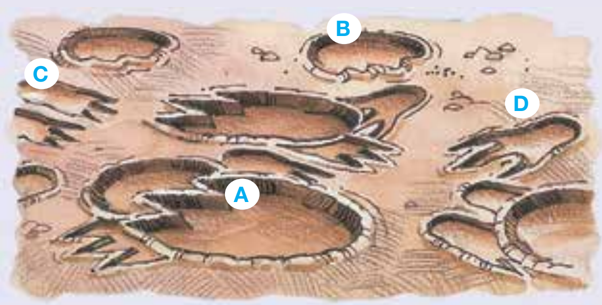
(b) Most organisms are broken down by _______________ after they die.
(c) If an organism is _______________ by sediments soon after death it may not _______________. The organism may _______________.
(d) _______________ wood looks like wood but the substances that make up the wood have been replaced by _______________.
(e) Insects may be preserved if they become trapped in _______________.
3. Use a diagram to **explain** the difference between a mould and a cast.
4. **Outline** the conditions that need to be present to ensure that fossilisation occurs.

Think and analyse

5. **Explain** why teeth, shells and branches are more likely to fossilise than muscle tissue, skin or flower petals.
6. **Explain** why fossils are usually found in sedimentary rocks rather than igneous rocks.
7. **Deduce** why very few organisms are preserved as fossils.
8. **Examine** the picture of the fossilised dinosaur at right. Then write a brief description of the animal, including what it may have eaten and how it may have moved. Why do you think it had so many large openings in its skull?

A fossilised dinosaur

9. **Examine** the dinosaur track below right to decide:
(a) which dinosaur walked along this track first, and which walked here last
(b) which dinosaurs most probably walked on two legs, and which most probably walked on four
(c) which dinosaur hopped
(d) which dinosaur was the heaviest.
10. Use an image search engine to locate images of each of the types of fossils listed in the table in Investigation 12.1. Cut and paste the pictures in a word document. Write a caption for each image. The caption should include the name of the fossilised organism shown in the picture, the location where the fossil was found and the type of fossil (e.g. cast).
11. There are a number of great fossil sites in Australia. Use the **Fossils** weblinks in the Resources tab and other sources to investigate one of the following fossil sites: Naracoote, Riversleigh, Bluff Downs, Murgon, Lightning Ridge.
Summarise information about the fossil site you have chosen under the following headings:
(a) Why the area is rich in fossils.
(b) Examples of fossils that have been found here.
(c) Age of the fossils found in this area.
(d) Important information revealed by the fossils found in this area.



12. Test your knowledge of all things old by completing the **Revelation 'Fossils'** interactivity. Success rewards you with a video interview with a paleontologist where you can see some real fossils.

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Explore more with these weblinks: Fossils

Try out this interactivity: Revelation 'Fossils' (int-1018)

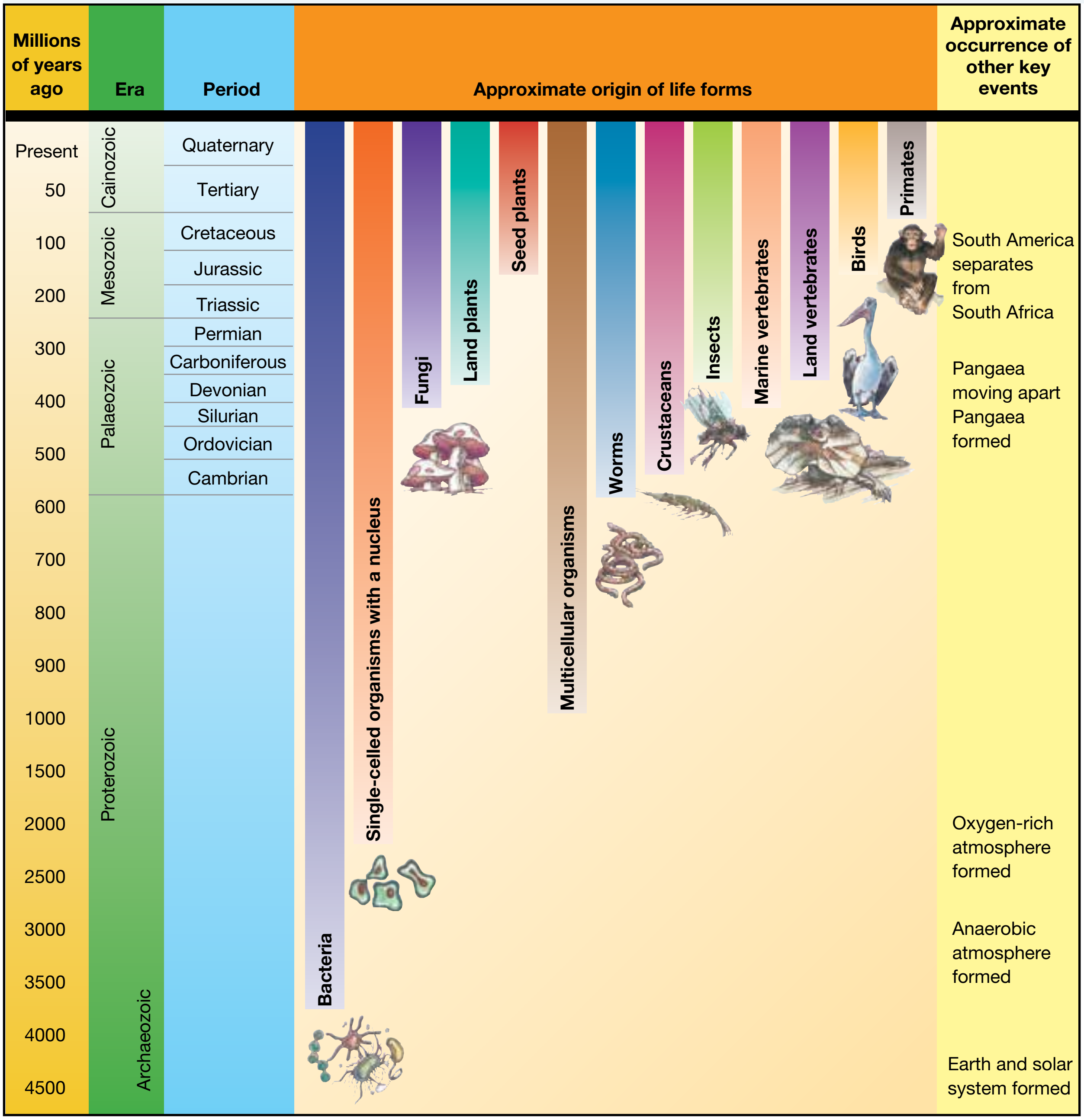
Complete this digital doc: Worksheet 12.1: Fossils (doc-12815)

12.3 Tracks through time

12.3.1 Geological time

The fossil record provides information about the order in which groups of living things appeared on Earth. Very ancient rocks contain evidence of only very simple bacteria like organisms. Fossil evidence of more complex life forms is found only in rocks that formed more recently.

The fossil record provides an incomplete picture of life as it existed on Earth.



Scientists estimate that the Earth is about 4.6 billion years old. To make it easier to talk about the history of the Earth, geologists have divided this time into 5 eras. These eras are in turn divided into shorter blocks of time called periods. For example the Mesozoic is divided into 3 periods: the Triassic, Jurassic and Cretaceous.

12.3.2 Life on earth

By studying rocks and fossils, palaeontologists have been able to piece together the story of life on Earth. The Precambrian Earth (prior to the Cambrian period) was very different to the planet we live on today. Evidence in rocks shows that there was no oxygen in the air. Animals could not have survived. There was also no ozone layer. The ozone layer screens out a large portion of the harmful UV rays from the sun. Without it, life on land would have been impossible and early life forms were restricted to bodies of water.

The oldest fossils are fossil evidence of prokaryotic life. Prokaryotes are single-celled organisms that lack a true nucleus. Bacteria are prokaryotes. Archae are another type of prokaryotic organism. They are similar to bacteria but their cell walls have a different composition and they also have some important genetic differences. Evidence of prokaryotic life forms has been found in rocks that are about 3.5 billion years old.

At some stage prokaryotes that could carry out photosynthesis appeared. As they carried out photosynthesis they produced oxygen. The oxygen reacted with some substances in the oceans initially, and then gradually built up in the atmosphere. The type of minerals found in ancient rocks show that oxygen levels increased dramatically around 2.2 billion years ago. Some of the oxygen would have been converted to ozone in the atmosphere and the ozone layer would have started to form.

Mosses and liverworts have no conducting tissue so they cannot grow very tall.

The first eukaryotic cells (cells with a nucleus) appeared around 1.8 billion years ago. They were followed by the first multicellular organisms. Multicellular organisms have more than one cell, so they can grow larger and their cells can become specialised for particular functions.

About 500 million years ago fish — the first vertebrates — made their first appearance in the fossil record. Plants then colonised the land, mosses and liverworts first. They could not grow very tall as they have no structures capable of taking water from the bottom to the top of the plant. However, ferns have such structures, and they were the next group of plants to appear on land.

HOW ABOUT THAT!

World's oldest fossils found in Pilbara, Australia

Recently scientists analysing rocks from the Pilbara discovered traces of ancient bacteria. The rocks have been estimated to be 3.49 billion years old. These could turn out to be the oldest fossils ever described.

The fossils consist of textures on the surface of sandstone. They are believed to be formed by the action of bacteria. The bacteria form thick mats. Sand becomes trapped and glued together in the bacterial mats and turns into rock over time.

The Pilbara once formed part of the shoreline of an ancient sea. In some areas sedimentary rocks that formed billions of years ago are exposed, so it is a great place to look for fossil evidence of the earliest life forms.

Strelley Pool in the Pilbara
Photo: David Wacey

Over 300 million years ago, during the Devonian and Carboniferous periods, plants had developed into a variety of complex forms. Close relatives of the horsetails, clubmosses and ferns formed vast ancient forests. Thick layers of their rotting remains became solidified over time, to form the coal beds found today. About 350 million years ago, the first seed-producing plants appeared. **Gymnosperms** were the dominant plants in the Permian, Triassic and Jurassic periods. Gymnosperms such as conifers, cycads and maiden hair trees are living descendants of the first pollen-producing plants. It was during the Cretaceous period, about 135 million years ago, when dinosaurs still flourished, that flowering plants appeared. During this period, **angiosperms** or flowering plants became the dominant plants. These plants were closely related to those found today.

12.3.3 Pollen power

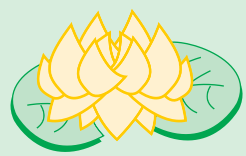
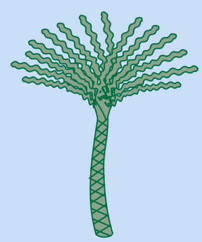
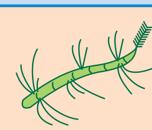
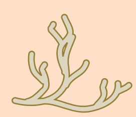
Fossilised pollen grains survive for millions of years. By studying ancient pollen, scientists can investigate vegetation that existed in the past. In Australia the oldest fossil pollen from a flowering plant is from the native holly genus *Ilex*. Millions of years ago, most of the surface of Australia was covered by forests. Over time, Australia gradually became drier. The change in climate resulted in fewer rainforests. Eucalypts, acacias and proteas, with their tough, hard leaves and often woody fruits, were well suited to these dry conditions. Pollen fossil evidence suggests that eucalyptus plants appeared about 30 million years ago.

Animals invaded the land as well. The fossil record shows that amphibians were the first vertebrates to live on land. Reptiles appeared next and dominated the landscape during the Triassic, Jurassic and most of the Cretaceous periods. Dinosaurs were the largest reptiles to ever live on Earth. As dinosaur numbers dwindled, two other groups of vertebrates became more dominant, birds and mammals. Invertebrates also took to the land around the same time as amphibians. Today, insects are the most abundant type of land invertebrate.

Conifers

A cycad

Geological table of plant evolution

Era	Period	Millions of years ago	Plant evolution
Cainozoic	Pleistocene	2	
	Pliocene	7	
	Miocene	26	
	Oligocene	38	
	Eocene	54	
	Palaeocene	65	Age of flowering plants
Mesozoic	Cretaceous	136	
	Jurassic	193	
	Triassic	225	Age of gymnosperms
Palaeozoic	Permian	280	
	Carboniferous	345	Age of ferns and horsetails 
	Devonian	395	
	Silurian	435	Age of early land plants 
	Ordovician	500	
	Cambrian	590	Age of algae
		600+	New fossils

12.3.4 Plants tell tales of history

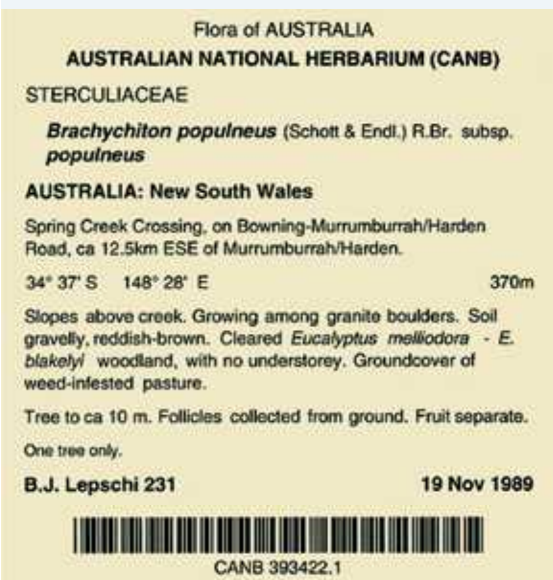
The Centre for Plant Biodiversity Research houses the Australian National Herbarium (ANH). The ANH contains over six million specimens of plants dating from the earliest days of European exploration, including specimens collected by Joseph Banks, the botanist who accompanied James Cook on board the *Endeavour*. Each specimen has its own story and history documented. This has enabled the ANH to maintain a historical record of over 200 years of changes to our vegetation. The records that ANH have kept have also enabled monitoring of the changes in the names given to plants over the last 200 years in Australia. Their plant information system, which is based on accurately named and labelled specimens, ensures the currency of names as we continue to find out more about our Australian plants.

12.3.5 ePlants

The Australian National Herbarium maintains a database in which you are able to search for information about many different plants online. AVH is a dynamic project that includes many plans for future developments. Perhaps you will be a part of this project in the future, providing images and descriptions or creating identification tools for future generations?

The Australian National Herbarium has maintained an extensive history of Australia's vegetation. The plant below is a Kurrajong, *Brachychiton populneus*, which is native to eastern Australia and was used as a source of water, food and bark by Aboriginal peoples.

An example of a label from the Australian National Herbarium: each label includes the plant names, basic details about where, when and by whom it was collected, and information about the habitat and the appearance of the plant. All these details are stored in a database so that they can be managed and made available for research and analysis.



Flora of AUSTRALIA
AUSTRALIAN NATIONAL HERBARIUM (CANB)
STERCULIACEAE
Brachychiton populneus (Schott & Endl.) R.Br. subsp. ***populneus***
AUSTRALIA: New South Wales
Spring Creek Crossing, on Bowning-Murrumburrah/Harden Road, ca 12.5km ESE of Murrumburrah/Harden.
34° 37' S 148° 28' E 370m
Slopes above creek. Growing among granite boulders. Soil gravelly, reddish-brown. Cleared *Eucalyptus melliodora* - *E. blakelyi* woodland, with no understorey. Groundcover of weed-infested pasture.
Tree to ca 10 m. Follicles collected from ground. Fruit separate.
One tree only.
B.J. Lepschi 231 **19 Nov 1989**
CANB 393422.1

Australia's Virtual Herbarium (AVH) is an online resource. It provides access to plant specimen data held by Australian herbaria.

HOW ABOUT THAT!

It is thought that over 4 000 000 000 000 different kinds of living things have, at one time, inhabited the Earth; however, only 250 000 of these organisms have been discovered as fossils.

INVESTIGATION 12.2

4.6 billion years of history

AIM: To create a timeline of the history of the Earth

You will need:

roll of toilet paper, cash register tape or similar

- Use the roll of paper to create a timeline of the history of the Earth. 1 cm of tape will represent 10 million years.
- The timeline will start 4.6 billion years ago.
  1 cm = 10 million years
  ___________ cm = 4.6 million years
  ___________ cm = 4.6 billion years
  ___________ m = 4.6 billion years
- Begin by copying and completing the table at right for each event shown in the fossil record diagram.
- Now mark the events on your timeline and illustrate your timeline with appropriate diagrams to represent the various events.

Event	When event occurred

Discussion

1. A student was describing the evolution of life on Earth and wrote 'for much of Earth's history not much happened'. Is the statement justified?
2. Explain why a long roll of paper is necessary to construct this timeline.

12.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Account for** the fact that humans could not have survived on Earth 4.5 billion years ago.
2. **Describe** the first living things to inhabit the Earth.
3. **Distinguish** between prokaryotes and eukaryotes.
4. Organise the following groups of plants in the order in which they appeared on Earth: flowering plants, ferns, algae, conifers, mosses.
5. List the five groups of vertebrates in the order in which they appeared on Earth.
6. **Identify** the following group of organisms:
   (a) first animals to live on land
   (b) first organisms to carry out photosynthesis
   (c) first plants to live on land.
7. Which characteristics make eucalypts well suited to the dry Australian environment?

Think

8. **Explain** why the fossil record is incomplete.
9. Suggest why flower fossils are very scarce.
10. If a botanist studies plants and a palaeontologist studies fossils, what do you think a palaeobotanist studies?
11. Why is it important to collect and catalogue samples of Australian plants?
12. What are the benefits of having a digital database containing all the details of the plant samples stored at the Australian National Herbarium? Why is a digital database better than just keeping printed records stored at the herbarium?

Skill builder

13. **Extract** the following information from the fossil record diagram.
    (a) List the three periods that make up the Mesozoic.
    (b) Which era and period are we currently in?
    (c) Which was first: the Jurassic or Triassic?
    (d) During which era and period did worms first appear in the fossil record?
    (e) How long have insects existed on Earth?
    (f) Look at the scale on the fossil record diagram carefully. Is it evenly spaced? **Discuss** whether setting out the scale in this manner is the best way of displaying the geological time scale.
    (g) The times given in the timeline are approximate. **Explain** why.
    (h) Dinosaurs were extinct by the end of the Cretaceous period.
        (i) Is it likely that some species of dinosaurs fed on seed plants? **Justify** your answer using information from the fossil record diagram.
        (ii) Could humans have caused the extinction of dinosaurs? **Justify** your answer using information from the fossil record diagram.

Investigate

14. Have the class divide into groups. Each group chooses a particular geological era or period to illustrate in poster form. Start by doing some research. What were the dominant life forms? What were the atmosphere and vegetation like? You may wish to include some labels within your drawing. Display your finished posters in the classroom as an illustrated guide to the major eras of evolution.
15. The ginkgo or maidenhair tree is often described as a living fossil. It is descended from trees that date back to the Triassic period, about 200 million years ago. Find out how it differs from the other groups of living gymnosperms, such as conifers and cycads. Suggest reasons for the differences.
16. Find out more about the following ancient plants:
    (a) giant clubmoss, *Archaeosigillaria*
    (b) horsetails
    (c) *Lepidodendron*
    (d) *Cooksonia*
    (e) *Baragwanathia.*

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Complete this digital doc: Worksheet 12.2: Geological time (doc-12816)

12.4 Analysing the fossil record

12.4.1 Absolute or relative

Fossils can provide a great deal of information about life forms that used to inhabit the Earth. How do we know which fossils are most ancient and is it possible to determine the actual age of some fossils?

The absolute age of a fossil is an estimate of its actual age. For example, a palaeontologist might determine that a fossil is around 100 000 years old. That is its absolute age. The methods used to date fossils are never 100% accurate, so the age is always an estimate. Some methods used to date fossils provide a more accurate estimate than others.

The relative age of a fossil indicates whether it is younger or older than other fossils or rocks, but it does not give its actual age. For example a palaeontologist might work out that a fossil is younger than fossil A (known to be 200 000 years old) but older than fossil B (known to be 50 000 years old), so the relative age of the fossil might be given as 50 000 to 200 000 years old.

12.4.2 Rock layers

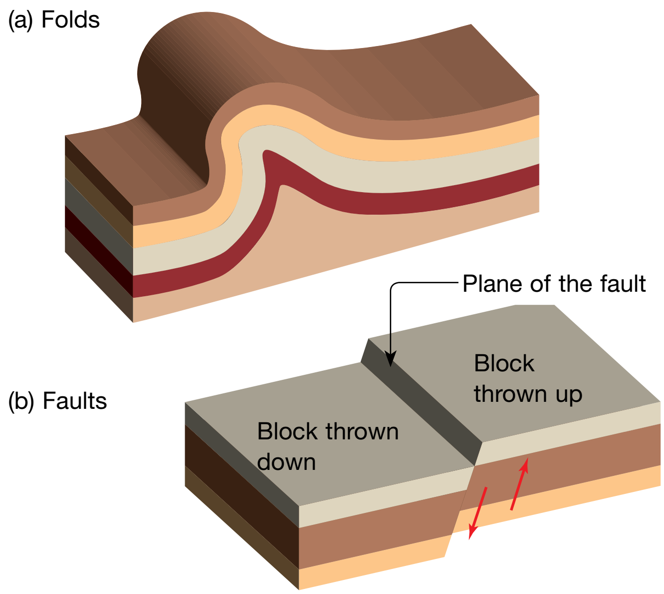
Fossils are found in sedimentary rock. Sedimentary rock forms from layers of sediments that have built up over time and have become cemented (stuck together). The older layers of sediments were laid down first, so if we look at a cross-section of sedimentary rock the older rock layers are usually on the bottom and the younger rock layers are at the top. If any living thing was trapped in the rock layer at the time it was laid down, there is a chance it may have been fossilised. It would therefore be approximately the same age as the rock that surrounds it. This can help us work out the relative age of the fossil.

This method for dating fossils does need to be used with care, however, as the plates in which the rocks lie are still moving. It is possible that a layer (or layers) containing fossils could have been thrust upwards by a sideways force to form a **fold**, or broken and moved apart in opposite vertical directions to form a fault.

The oldest rocks discovered so far have been found in Canada and are thought to be around 4550 million years old. The Earth is thought to be about 4600 million years old.

We can determine the relative age of fossils by looking at their position in rock layers.

The formation of folds and faults can cause changes in the rock layers.

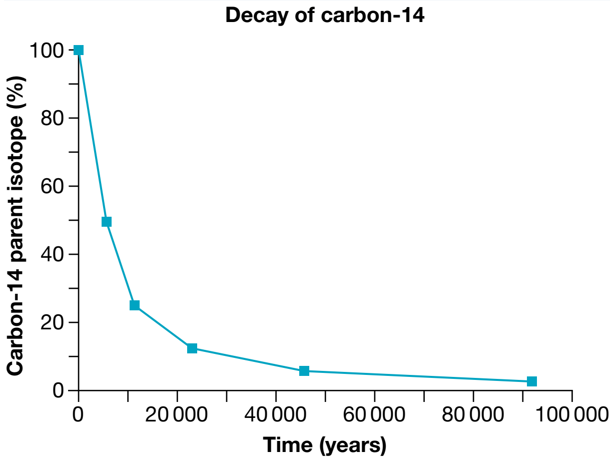


12.4.3 Carbon dating

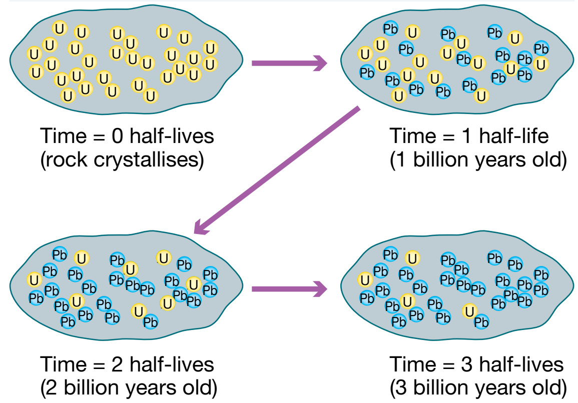
Radiometric dating is a technique used to determine the absolute age of rocks and fossils. The age of fossils up to 50 000 years old can be determined by a type of radiometric dating called carbon dating. All living things contain carbon. Most of the carbon in living things is carbon-12 but a small amount is carbon-14. Carbon-14 is not stable and decays into nitrogen over time. After an organism dies, the carbon-14 decays but the carbon-12 does not so that the ratio of carbon-14 to carbon-12 decreases gradually. By measuring this ratio we can tell how old the fossil is.

Radiometric dating can also be used to determine the age of ancient rocks. Instead of measuring the levels of carbon-14, other isotopes may be used. For example, the amount of uranium-238 and uranium-235 in the rock might be measured. Uranium-238 decays into lead-206. It has a half-life of 4.47 billion years. That means that it takes 4.47 billion years for half the uranium-238 in the rock to be converted to lead-206. Uranium-235 decays into lead-207 and has a half-life of 704 million years. By working out the amount of each type of uranium that has been converted to lead in the rock, it is possible to determine the age of the rock. Both forms of uranium decay a lot more slowly than carbon-14, so this technique makes it possible to date rocks that are much older than 50 000 years old.

Older fossils contain less carbon-14 than younger fossils.



Over time the uranium present in the rocks decays into lead. The half-life of uranium is the amount of time it takes for half the uranium initially present in the rock to decay into lead.



12.4 Exercise: Remember and think

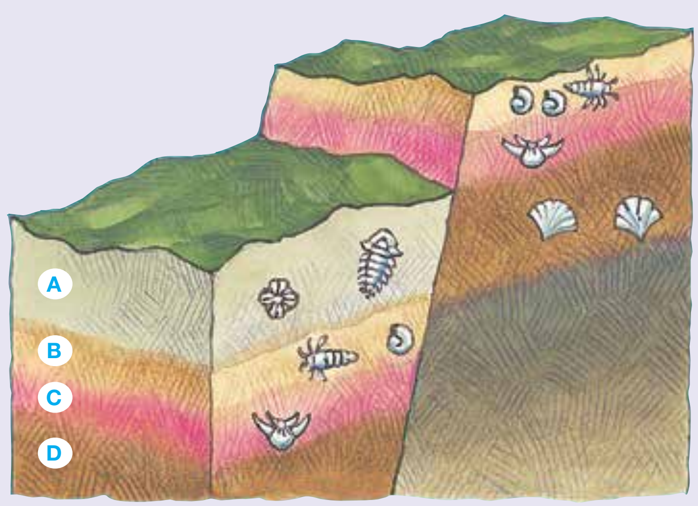
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Copy and complete the statements below using the following words: age, bottom, carbon-14, faults, folds, lead-206, top.
   (a) In sedimentary rock layers the youngest rock is usually at the ______________ and the oldest rock is at the __________________.
   (b) Fossils are approximately the same _____________ as the layer of rock in which they are found.
   (c) The formation of ________________ and _________ can disturb rock layers.
   (d) A fossilised organism that died 15 000 years ago will contain more ___________ than a 30 000 year old fossil.
   (e) To date rocks older than 50 000 years old scientists might measure the amount of uranium-238 and _________________ in the rock.

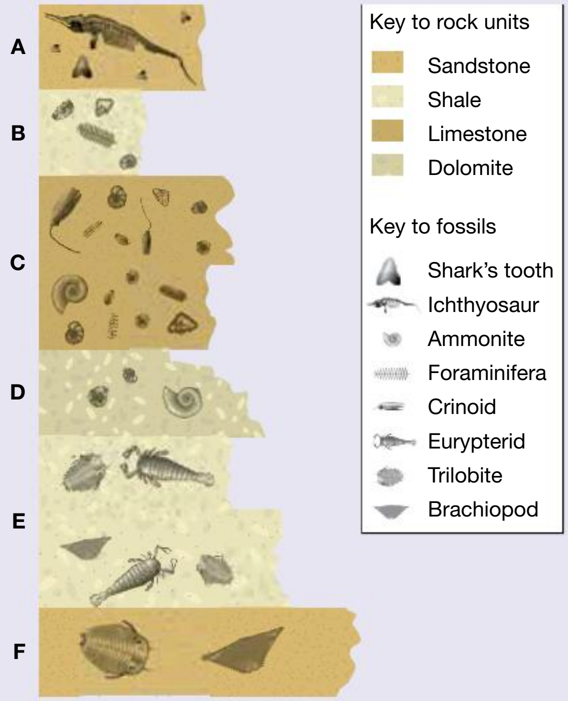
Think and analyse

2. **Contrast** absolute and relative dating.
3. **Explain** why carbon dating cannot be used to date objects older than 50 000 years.
4. The layers of rock shown in the illustration at right have been disturbed by plate movements. Answer the questions that follow.
   (a) Was the plate movement caused by folding or faulting?
   (b) Which of the labelled layers of rock is youngest? **Justify** your answer.
   (c) Which of the labelled layers of rock is oldest? **Justify** your answer.

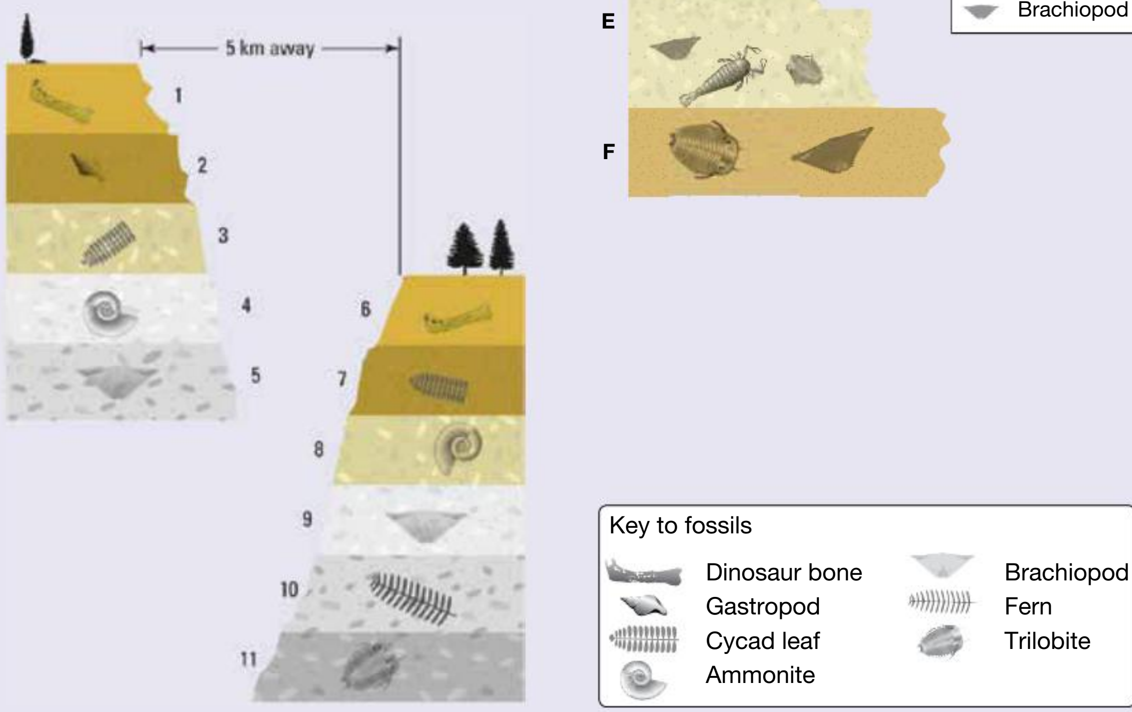


5. **Examine** the graph above showing the decay of carbon-14. The half-life of an isotope is the amount of time it takes for its radioactivity to halve.
   (a) How long did it take for the radioactivity of carbon-14 to drop to 50%?
   (b) What is the half-life of carbon-14?
   (c) Will the radioactivity ever be zero? **Explain** your answer.

6. Study the diagram at right. It shows some layers of sedimentary rocks and the fossils found in some of the layers of rocks. Use the diagram to **deduce** the answer to these questions:
   (a) Which rock layer is:
      (i) youngest
      (ii) oldest?
   (b) Is layer B younger or older than layer C?
   (c) If ammonites became extinct 65 million years ago, what can we say about the fossils in layer C?



7. **Examine** the diagram below and **deduce** the answers to the following questions.
   (a) Write down the names of the fossils in order from youngest to oldest.
   (b) Out of all the fossil layers numbered 1–11 which layer is oldest? How can you tell?



Names of fossil for each layer:
1 = Dinosaur bone
2 = Gastropod
3 = Cycad leaf
4 = Ammonite
5 = Brachiopod
6 = Dinosaur bone
7 = Cycad leaf
8 = Ammonite
9 = Brachiopod
10 = Fern
11 = Trilobite.

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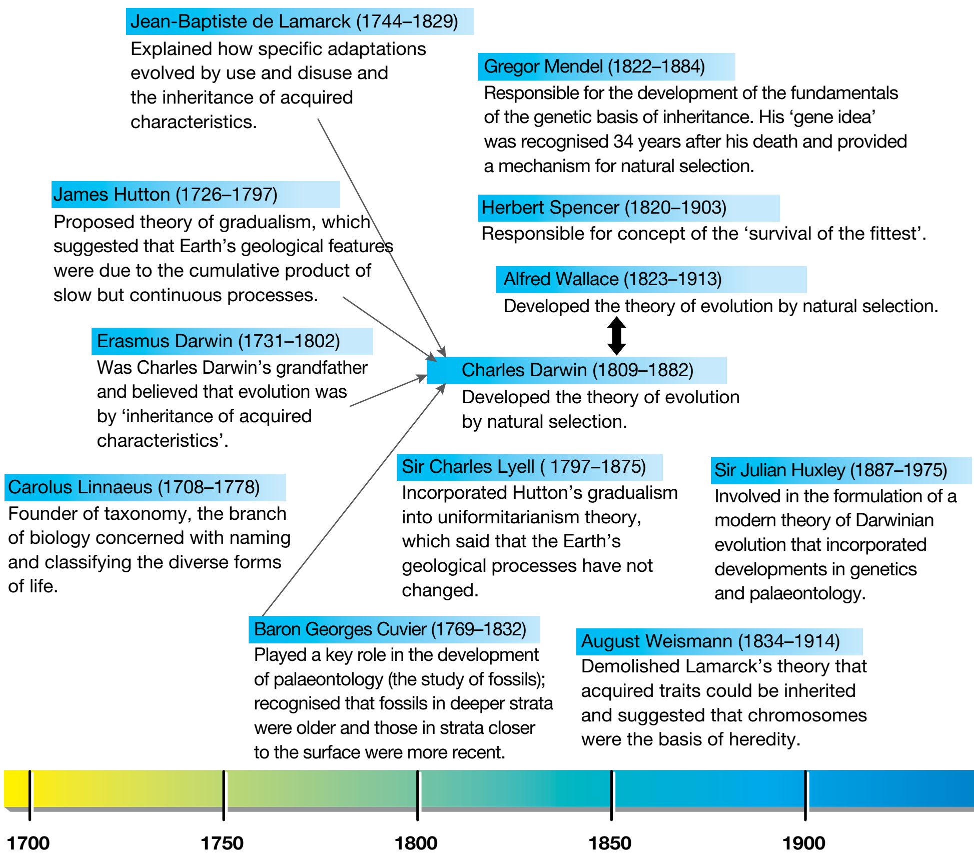
Complete this digital doc: Worksheet 12.3: Ages of fossils (doc-12817)

12.5 The theory of evolution

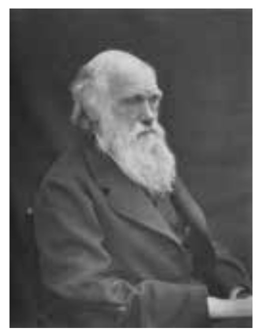
12.5.1 The development of a theory

The theory of evolution is that every organism on Earth is a descendant of those that lived millions of years ago. **Species** change and evolve, and two different species may be related, through many, many generations, to an ancestral species (a **common ancestor**). When these ideas were first presented they were very controversial. Until this time, most scientists believed the Earth's organisms were the unchanging work of a creator, God, and that the Earth was only a few thousand years old. Today the theory is widely accepted by the scientific community.

The idea that living things have evolved over time is usually associated with Charles Darwin, but it was proposed before Darwin was even born. The timeline below shows a few of the scientists whose ideas have contributed to the current theory of evolution.




Alfred Wallace


Charles Darwin

12.5.2 Lamarck's ideas: considered then modified

Jean Baptiste Lamarck (1744–1829) was one of the first scientists to suggest that evolution occurred; that is, that populations of organisms changed over time, and that new species had arisen and others had died out. He proposed a mechanism for evolution that was initially considered then later rejected. He suggested that changes acquired by an individual during its lifetime could be passed on to its offspring. For example, giraffes had become long necked because they had stretched towards leaves high up on trees, and this elongated neck had been passed on to their offspring. He also believed that if an individual did not use a particular feature, it would shrink and gradually be lost over succeeding generations. Although his theory of the inheritance of acquired characteristics is now discredited, he made many valid observations about diversity in living things.

There are many examples that illustrate that Lamarck's proposed mechanism for evolution is not an accurate description of the way evolution occurs. Lifting weights can increase muscle size, but body builders do not produce children who are unusually muscular. Plastic surgery can be used to modify the shape of a nose, but a person who has cosmetic surgery on their nose will not pass on the new nose to their children. August Weismann, a German biologist, carried out a simple experiment to test Lamarck's hypothesis. He chopped off the tails of some rats and allowed the rats to breed. If Lamarck had been correct, the characteristic the rats had acquired during their life (a severed tail) should have been passed on to the rats' offspring. When the rats produced a litter of baby rats all the babies had full length tails, thus showing that a characteristic acquired during the life of the rats had not been passed on to the next generation.

Surgery has changed this woman's nose but her genetic make-up has not been changed by the surgery. She may pass on the allele that codes for a bumpy nose to her children.

12.5.3 Charles Darwin

Darwin spent most of his life developing his theory of evolution by natural selection. As a child he showed a fascination for the natural world. His father would have liked him to become a doctor or clergyman but his real passion was in the area of Science. Some of his teachers at university recognised his talent and recommended him when naval lieutenant Robert FitzRoy was looking for someone to accompany him on a trip to chart the coastline and investigate the fauna and flora of South America and other southern landmasses. Darwin was thus invited to join the crew of HMS *Beagle.* He was just 22 when the ship set sail in 1831. The trip lasted 5 years and took him to the Brazilian jungles, the Andes Mountains, the Argentine grasslands and Australia. Darwin's travels opened his eyes to the vast range of animal and plant species on Earth.

The *Beagle*'s voyage

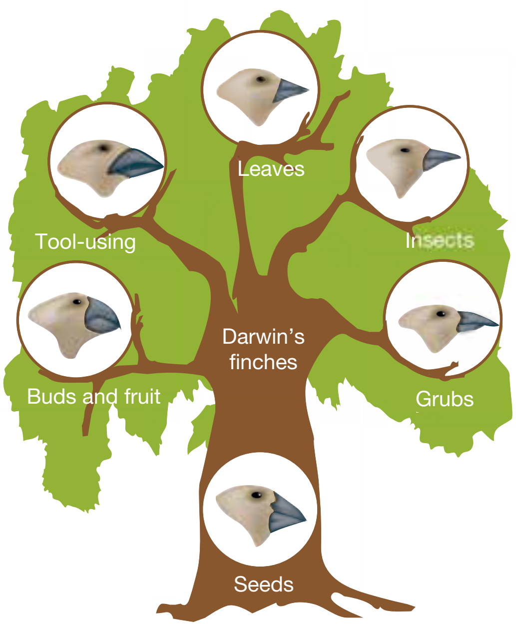
Darwin was particularly fascinated by variations between similar species. During his journey, Darwin visited the Galapagos Islands, which are home to at least 13 species of finch. He noticed that the different finch species were similar in colour and size, but had **variations** in their beaks that made them suited to the food sources available on their particular island. Some used twigs to extract insect larvae from tree branches, some drank blood from seabirds, some removed ticks from tortoises, and some ate seeds, leaves and flowers.

He proposed that all species of finches in the Galapagos were the descendants of one shared, ancestral species, a ground-dwelling, seed-eating finch, which had migrated out to all the islands from the mainland. Over many generations the different groups of finches had evolved to suit their different environments and feeding habits. The groups of finches are now so different from one another that they do not interbreed. They have become separate species.

Charles Darwin spent 61 days in Australia in 1836. He visited Sydney, Bathurst, Hobart and King George's Sound in Western Australia. In Bathurst he was fortunate to see a platypus. He had heard about the curious creatures and made the observation that they behaved and were similar in appearance to water rats. Despite being clearly different species, they had similar features that made them ideally suited to life in streams. The observations he made and the specimen he collected while in Australia influenced his thinking about evolution.

Charles Darwin was reluctant to publish his theory of evolution by natural selection. He wrote an early draft of his theory as early as 1841 but did not present his ideas formally until much later. In the meanwhile another naturalist by the name of Alfred Wallace was coming up

Darwin observed that each species of finch had a beak that matched its method of obtaining food.

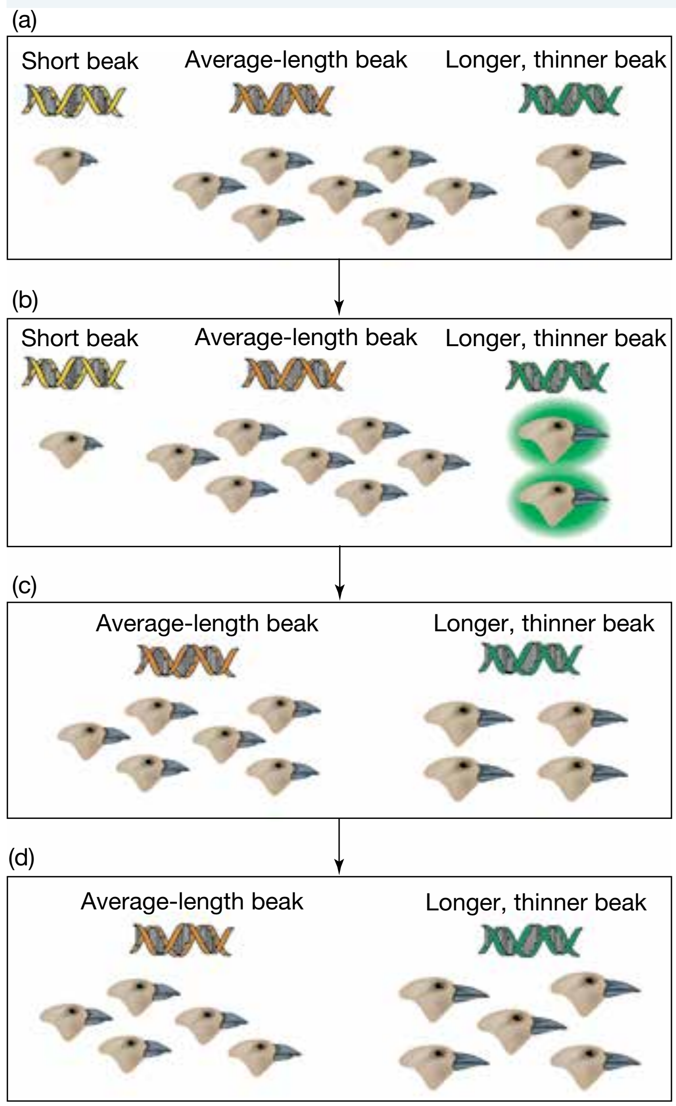


(a) A population of finches live in an area where insects are common.

(b) Two members of the population have beaks well suited to obtaining insects.

(c) When the population reproduces, these two finches are better fed and have more offspring than the others. Some particularly short-beaked finches do not survive to reproduce.

(d) The next generation has, on average, longer beaks.

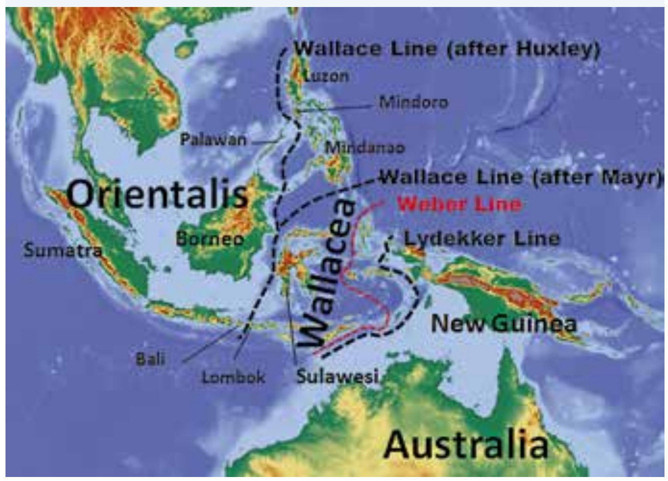


with similar ideas. Alfred Wallace's writings prompted Charles Darwin to publish his *Origin of Species*. Like Darwin, Wallace travelled extensively (in what is today known as Indonesia) and made many detailed observations of the variations between species. Wallace wrote to Darwin in 1858 from the East Indies, telling him that he had a theory about evolution and **natural selection**. Darwin was shocked to realise Wallace had reached the same conclusions as himself. Darwin later described Wallace's writings as an almost perfect summary of his own life's work. Darwin was encouraged by his colleagues to submit both his paper and Wallace's to the Linnean Society science conference held in London on 1 July 1859. Wallace is recognised as a co-founder of the theory of evolution by natural selection.

12.5.4 Biogeography

Biogeography, the study of variation in living things in relation to geographical regions, is the name given to the studies that led Darwin and Wallace to propose their evolutionary theories. They observed in their travels that species living in the same area, such as the Galapagos finches, were more similar to each other than to species living in similar habitats much further apart. Wallace also observed that geographical features such as oceans, rivers and mountain ranges often marked the boundary of a species' range. When Wallace travelled through Indonesia, he noticed that the animals and plants found on the islands of Sumatra and Java (in the North West region of Indonesia) were similar to those found in Asia. The animals and plants of New Guinea (in the South East of Indonesia) were more like those of Australia. He traced a line on a map snaked among the islands to show the boundary between the two regions. The line is now known as Wallace's Line. Later he identified 6 regions of the world with distinct fauna and flora. These are shown in the map at right. Before the theory of evolution was accepted, it was thought that species had been created with particular adaptations that made them suited to the environment in which they lived. If that had been the case, the same species should have been found wherever conditions were similar. Wallace and Darwin observed that this was not the case. They separately hypothesised that the adaptations were the result of an evolutionary process.

The region to the left of Wallace's line is ecologically quite different to the region to the right.



12.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** the two people jointly credited with developing the theory of evolution by natural selection.
2. How old did many scientists believe the Earth to be before Darwin's writings were published?
3. **Outline** what Darwin observed about the beaks of finches in the Galapagos Islands.
4. In your own words, **define**:
   (a) common ancestry
   (b) evolution.

Think

5. **Extract** the answers to the following questions from the from the timeline. Which of the scientists
   (a) was the first to be born
   (b) lived the longest

(c) was born before Darwin
(d) was born after Darwin
(e) lived at the same time as Darwin
(f) is attributed with founding taxonomy
(g) played a key role in the development of palaeontology
(h) is responsible for the development of the fundamentals of genetics
(i) developed the theory of use and disuse and the inheritance of acquired characteristics
(j) demolished Lamarck's theory and reasoned that chromosomes were the basis of heredity?

6. What was the purpose of the trip aboard *HMS Beagle* that Darwin was invited to join?
7. In Weismann's experiment what was the dependent variable?
8. **Explain** why a finch with a short powerful beak would be more likely to survive in an environment where seeds were the main food source.
9. Why is it important for scientists to publish their work?
10. In the days of Darwin there were no telephones or email. Darwin communicated with other people interested in evolution through letters. At the time that the *Beagle* set sail photography was in its infancy. Images of the animals and plants seen on the voyage consisted of hand drawings rather than photos.
    (a) Suggest how phone or email communication might have impacted on the development of the theory of evolution by natural selection.
    (b) What would be the advantages of taking photos rather than drawing biological specimens?
    (c) Today a whole range of cameras, including digital eyepieces for microscopes, are available, yet researchers sometimes prefer to use a drawing rather than a photograph to describe the structure of a specimen. Suggest why.
    (d) In addition to communication devices and cameras, what other technology could be used today to make the trip aboard the *Beagle* safer and easier?

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Complete this digital doc: Worksheet 12.4: Evolution (doc-12818)

12.6 Natural selection

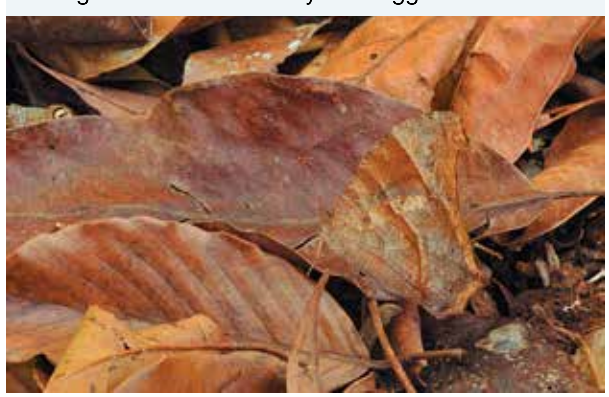
12.6.1 Producing offspring

Darwin and Wallace suggested that evolution occurs by natural selection. According to this theory, organisms that are well suited to their environment are more likely to survive long enough to produce offspring and also have a better chance of having a large number of offspring. Organisms that are not well suited to their environment are out-competed, die young and produce few or no offspring.

12.6.2 Variation

There are variations or differences between members of a species. In a rainforest some tree ferns grow faster and produce more spores than others. In a herd of sea lions certain males will grow larger and have deeper voices. Some sharks will be faster and have a better sense of smell than others. Butterflies of the same species may have slightly different patterns and colours on their wings. Importantly, certain variations give an advantage. The faster sharks are more likely to catch their prey and thus be well fed. The larger sea lions will win fights against other males and thus the right to mate with more females. The faster growing tree ferns will not be shaded by other ferns and will have sufficient

Camouflage reduces this butterfly's chance of being eaten before she lays her eggs.



light to continue to grow. The butterfly with the pattern that offers the best camouflage is less likely to be eaten before it can mate and lay eggs.

Individuals with favourable variations are more likely to survive longer and produce more offspring. Those that possess unfavourable variations are likely to die having produced few or no offspring. A bird born with a long thin beak when hard seeds are the only food available will break its beak trying to eat the seeds and die of starvation before it can reproduce. A peacock with a small drab tail will fail to attract a mate and will not have an opportunity to produce offspring. A bright red caterpillar crawling in green vegetation is likely to be eaten by a bird and never go on to become a butterfly and reproduce.

Some sharks are faster, giving them an advantage over slower sharks.

12.6.3 Selection

The different living (biotic) and non-living (abiotic) **selective agents** in an environment select for survival those individuals who are best at surviving and obtaining what they need. In a rainforest the low availability of light is a selecting agent. Plants that can get access to light survive. Predators can act as selecting agents. Individuals that can outrun or hide from the predator live on and reproduce. Chemicals and disease-causing organisms can also be selective agents. When DDT was first used as an insecticide it killed most insects. A few were naturally resistant to DDT. They survived, reproduced and passed on their natural resistance to their offspring. The process was repeated over many generations and now many insects are resistant to DDT. Myxomatosis is a virus that, when first released, was deadly to most rabbits. It acted as a selecting agent. Those rabbits that did not die reproduced and passed on the resistance to the virus. The proportion of rabbits that are not killed by myxomatosis has increased.

The first plant to grow gets the greater share of limited light.

12.6.4 Competition

Often in nature there is not quite enough to go around. A pride of lions may fight each other for larger shares of a kill and sea lions compete for mates. **Competition** is the biological term for the battle between members of the same species for a share of any limited resources.

Elephant seals compete for territory and access to mates.

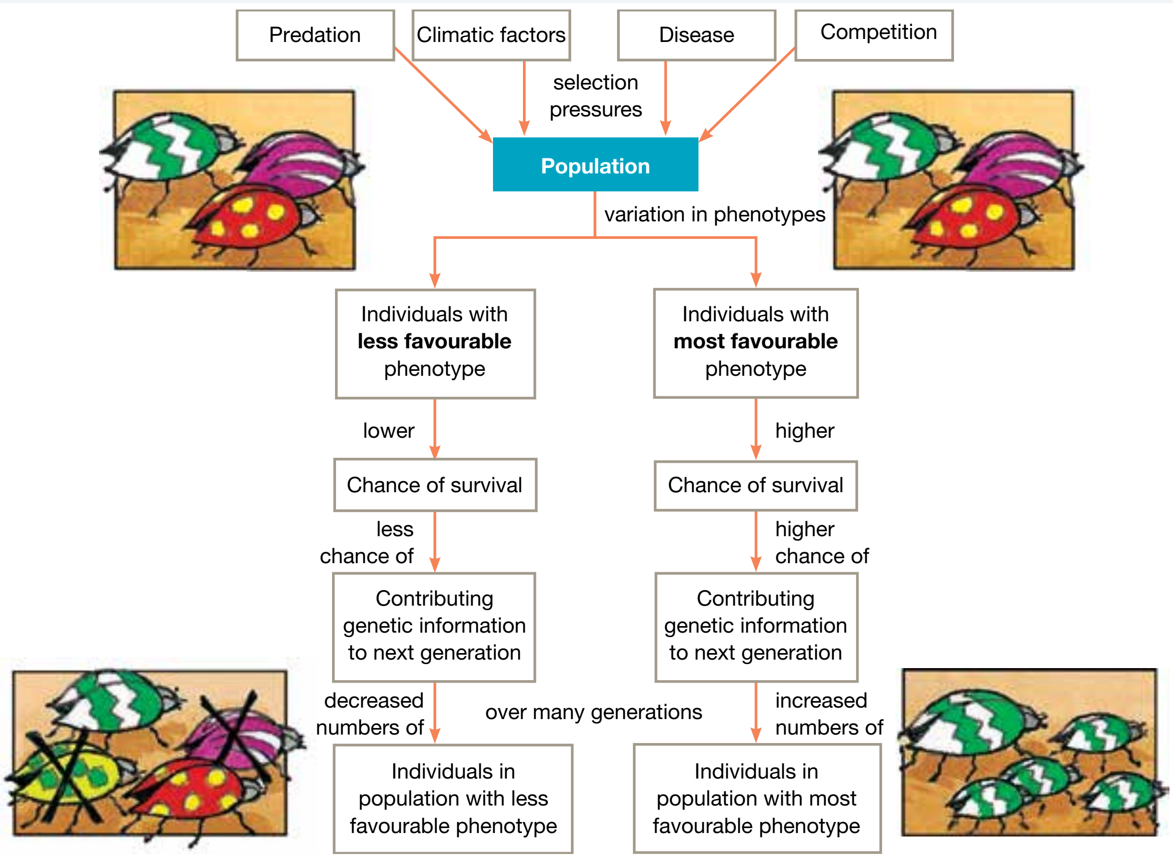
12.6.5 Survival of the fittest

Darwin's theory of evolution by natural selection is often described as *survival of the fittest.* 'Fittest' in this instance does not mean those who can do the most sit-ups! It means that in a population with a range of features, those who are the best 'fit' to their environment are selected, survive and breed more successfully than their rivals.

12.6.6 Selection at work

The Galapagos finches (see section 12.5.2) provide an excellent example of natural selection. Darwin proposed that an ancestral species of finch had spread to a number of islands. In each place, different sources of food were available, and those individuals who had beaks that were better suited to obtain the local food survived and reproduced more successfully than others. The offspring of such birds also had these beaks and were more successful, until eventually the whole population of finches occupying that niche showed that adaptation. Over many generations, each group evolved to have a beak suited to its particular food.

Natural selection is the mechanism for evolution.



INVESTIGATION 12.3

Modelling natural selection

AIM: To model natural selection

You will need:

100 green toothpicks (or rubber bands)
100 red toothpicks (or rubber bands)

- Scatter 50 green toothpicks and 50 red toothpicks over an area of grass measuring at least 10 m × 10 m. The toothpicks represent caterpillars.
- One student will be the evil caterpillar-eating bird (ECEB). Allow the ECEB 15 seconds to ‘eat’ (pick up) as many of the caterpillars as she can.
- Count how many caterpillars of each colour were eaten. That will tell you how many caterpillars of each colour are left in the grass. Record these figures in a result table similar to the one shown below.
- Allow the caterpillars to ‘breed’. For every pair of caterpillars of a particular colour, add a third caterpillar of the same colour (e.g. if you have 15 green toothpicks [7 pairs] and 10 red toothpicks [5 pairs] left in the grass you should scatter an additional 7 green and 5 red toothpicks in the grass). Record the number of each type of caterpillar after breeding in your result table.
- The ECEB will now have two further 15-second feeding frenzies. After each feeding frenzy, record the number of each type of caterpillar left in the grass, and allow the caterpillars to ‘breed’.

Discussion

1. Copy and complete the table below.

	Number of caterpillars	
Time	**Red**	**Green**
Start	50	50
After first feeding frenzy		
After first mating		
After 2nd feeding frenzy		
After 2nd mating		
After 3rd feeding frenzy		
After 3rd mating		

2. By the end of the experiment were there more green or red caterpillars? Explain why.
3. Do you think one type of caterpillar might eventually become extinct? Why.
4. Explain how this experiment models natural selection.

12.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Match the following terms to the correct definitions:

Terms	Definitions
(a) Variation	(i) The process by which the biologically fittest individuals survive and reproduce more successfully than others
(b) Natural selection	(ii) Genetic change in a species over generations
(c) Competition	(iii) The range of different structural and behavioural differences in a species
(d) Adaptation	(iv) The fight for limited resources between individuals of a species
(e) Evolution	(v) A feature which improves an organism’s chance of survival in its environment

2. **Identify** whether the following are *true* or *false*. Correct any false statements.
   (a) During its lifetime, an animal gains adaptations that make it more suited to its environment.
   (b) In natural selection, one species competes against another and the unsuccessful one dies out.

Think

3. **Distinguish** between the everyday meaning of fitness and the concept of biological fitness.
4. Penicillin is an antibiotic. Antibiotics are used to treat many diseases caused by bacteria. When penicillin was first discovered it was effective against most bacteria. There are now many strains of bacteria which are not affected by penicillin. **Account for** this using the theory of evolution by natural selection.
5. **Outline** how the process of natural selection can explain why male peacocks have such large colourful tails.
6. Webbed feet are seen in a number of aquatic animals including ducks and the platypus. **Explain** how the process of natural selection could have resulted in such different species having the same adaptation.

Investigate

7. The English peppered moth comes in the two varieties shown below. Find out why the proportion of each type of moth has changed since the industrial revolution. (*Hint:* The industrial revolution caused the bark of trees to darken in areas where the peppered moths live.)

There are two types of peppered moths: a dark type and a light type.

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Complete this digital doc: Worksheet 12.5: Struggling to survive (doc-12819)

12.7 Speciation

12.7.1 Do we belong to the same species?

Natural selection explains how species change over time, but how do new species evolve?

A species is a group of organisms capable of interbreeding to produce fertile offspring. The dogs in the photo at right belong to different breeds but they all belong to the same species. They can be crossed and the puppies produced will generally be fertile — they will be able to produce offspring. Dogs and cats do not belong to the same species. Even if a cat and a dog mated no offspring would be produced. It is not possible for an egg from one of these species to be fertilised by a sperm cell from the other species and produce a viable zygote. There are a few species that can interbreed but the offspring are not fertile. A lion and a tiger can occasionally produce a sterile liger and a horse and a donkey have been known to produce a mule.

12.7.2 New species

The formation of new species is called **speciation**. There are two ways in which speciation can occur. **Phyletic evolution** occurs when a population of a species progressively changes over time to become a new species. **Branching evolution** or **divergent evolution** is more common; in this case, a population is divided into two or more new populations that are prevented from interbreeding. When different selection pressures act on each population, different characteristics are selected for. Over generations, these new populations may become so different from each other that they can no longer interbreed and produce fertile offspring. At this point, they have become two different species.

Divergent evolution

Divergent evolution is a type of evolution in which new species evolve from a shared ancestral species. That is, two or more new species share a common ancestor. At some point in history there has been a barrier (such as a geographical barrier, for example a mountain or ocean) that has divided the population into two or more populations and has also interfered with interbreeding between the populations.

Exposure of these populations to different selection pressures will result in the selection of different variations or phenotypes. Over time, the populations may become so different that even if they were brought back together they would be unable to produce fertile offspring. It is at this point that they are referred to

Speciation is a process by which a new species develops from another.

1 Variation of characteristics is present in a population.

↓

2 The breeding population becomes isolated.

↓

3 Different characteristics arise through random genetic drift, mutation and environmental pressures.

↓

4 The environment changes. Because of selection, some characteristics are favoured over others. Those best suited to the environment survive.

↓

5 Survivors reproduce and pass on favourable genes and features to offspring.

↓

6 The frequency at which the genes for the new characteristics appear increases.

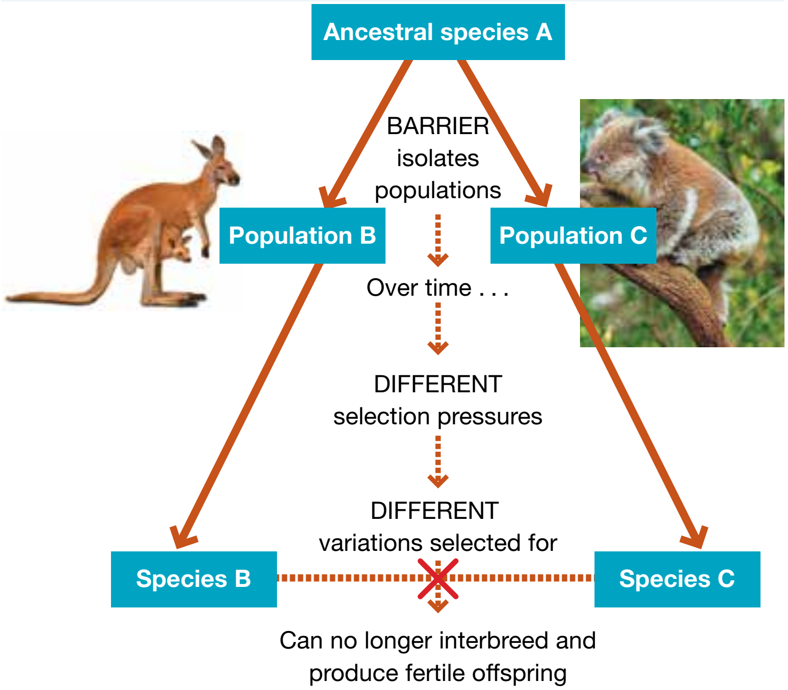
↓

7 The isolated population is now quite different, producing a new species.

as different species. Speciation has occurred.

Darwin's finches are examples of divergent evolution. They share a common ancestor, but over time and generations, different selective pressures have led to the selection of different variations most suited to a particular environment or available niche.

Divergent evolution



Adaptive radiation

Adaptive radiation is said to have occurred when divergent evolution of one species has resulted in the formation of many species that are adapted to a variety of environments. Darwin's finches and Australian marsupials are two examples. Australian marsupials are thought to have evolved from a common possum-like ancestor. The photographs below show examples of species that have arisen from a common ancestor.

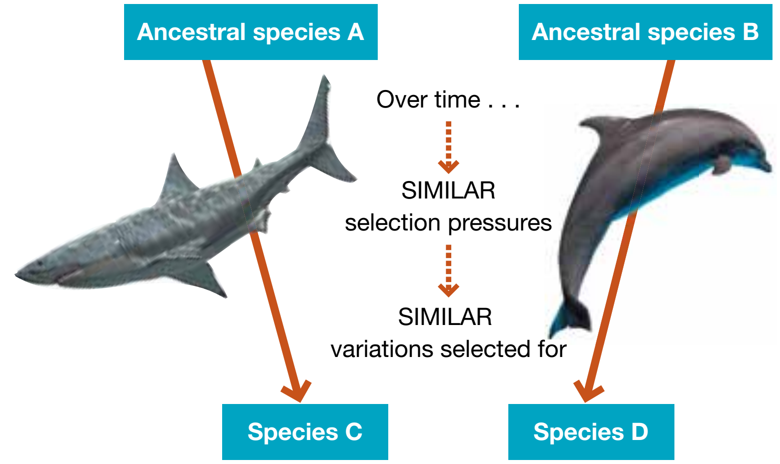
Australian marsupials show adaptive radiation as they have evolved from a common ancestor but, due to different selection pressures, different characteristics have been selected.

Convergent evolution

In divergent evolution, different selection pressures lead to the selection of different variations in evolution from a common ancestor. **Convergent evolution** is the opposite. Convergent evolution is the result of similar selection pressures in the environment selecting for similar features or adaptations. These adaptations have not been inherited from a common ancestor.

Sharks and dolphins have a similar body shape and colour, yet

Convergent evolution



(a) The South American anteater, (b) the African aardvark, (c) the South-East Asian pangolin and (d) the Australian echidna share similar features. These features were selected for because they gave them a selective advantage in obtaining an available food supply within their environment, rather than because of a recent common ancestry.

sharks are fish whereas dolphins are mammals. They both live in the ocean. The features they share are the result of similar selection pressures.

Coevolution

The evolution of one organism can sometimes be in response to another organism. Examples of this coevolution include parasites and their hosts, or birds and plants. If you look at the features of birds and the flowers that they pollinate, you may notice that some birds have evolved specialised features, such as beaks that are well suited for obtaining nectar for a flower with a particular shape. The plants have evolved flowers that may be of a particular colour that is attractive to its pollinator, and nectar that not only attracts but rewards the bird for its task of being involved in pollination.

12.7.3 Extinction

Extinction is the loss or disappearance of a species on Earth. Extinction of a species may influence the evolution of another species, as it may provide the opportunity to move into the niche that the extinct species occupied.

12.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

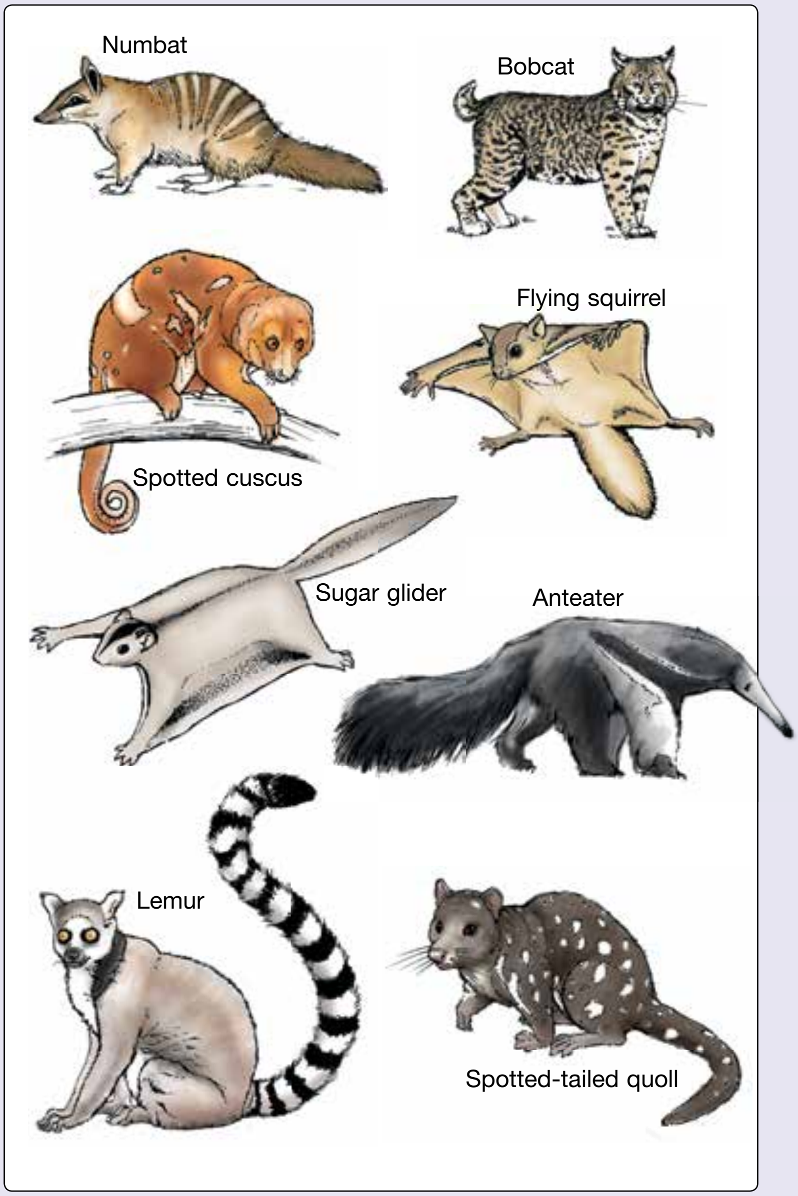
Remember

1. What is meant by the term *speciation*?
2. **Describe** how a new species evolve.
3. **Distinguish** between (a) divergent evolution and (b) convergent evolution.
4. **Describe** an example of divergent evolution.
5. **Outline** the relationship between adaptive radiation and divergent evolution.
6. **Describe** an example of adaptive radiation.
7. **Identify** examples of organisms that show convergent evolution.
8. What is meant by the term *extinction*?
9. Select appropriate terms from the following list and use flow charts to describe:
   (a) divergent evolution
   (b) convergent evolution.
   Ancestral species A, Similar selection pressures, Similar variations selected for, Species C, Population B, Different selection pressures, Over time, Barrier isolates populations, Different variations selected for, Species D, Population C, Ancestral species B, Species B, Can no longer interbreed and produce fertile offspring

Think and analyse

10. The figures at right show two species of North American hares that are closely related and share a common ancestor. The snowshoe hare, *Lepus americanus* (top), lives in northern parts of North America where it snows in winter. The black-tailed jack rabbit, *Lepus californicus* (bottom), lives in the desert areas.
    (a) **Identify** differences between these hares.
    (b) Suggest reasons for these differences.
    (c) Suggest how these differences came about.
    (d) Is this an example of convergent or divergent evolution? Explain.

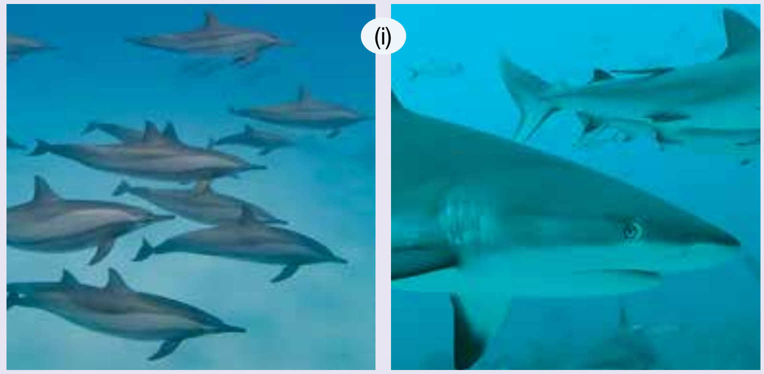
11. **Identify** where each of the figures shown belong in the convergent evolution table at the bottom of the page.

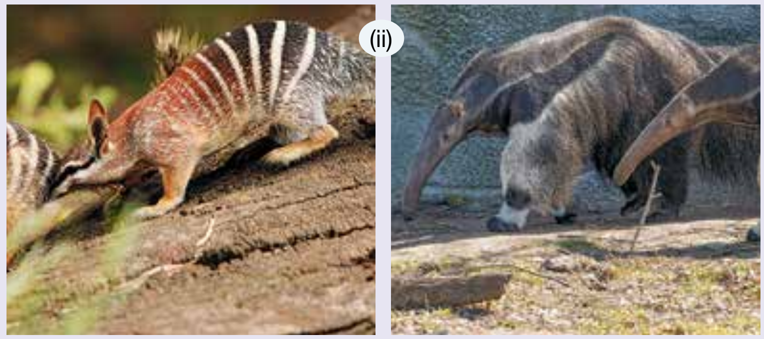


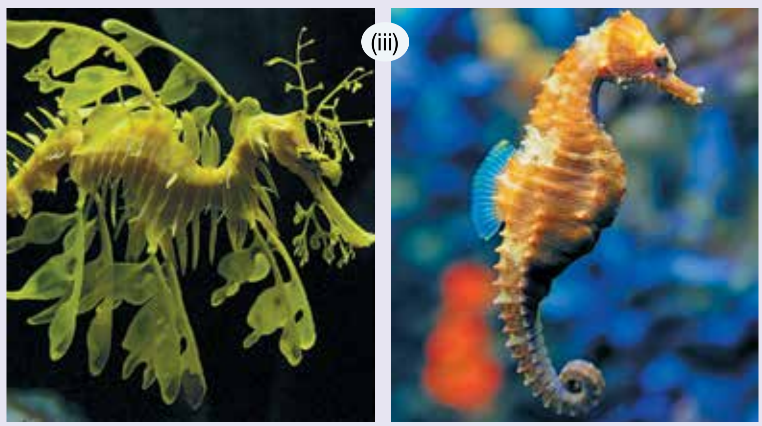
Niche	Placental mammal	Australian marsupial
Anteater		
Cat		
Climber		
Glider		

12. Carefully examine each of the pairs of organisms shown at right. **Identify** whether each pair is an example of convergent or divergent evolution.
    (i) Dolphin and shark
    (ii) Numbat and anteater
    (iii) Sea dragon and seahorse
    (iv) European goldfinch and pine siskin (finch)

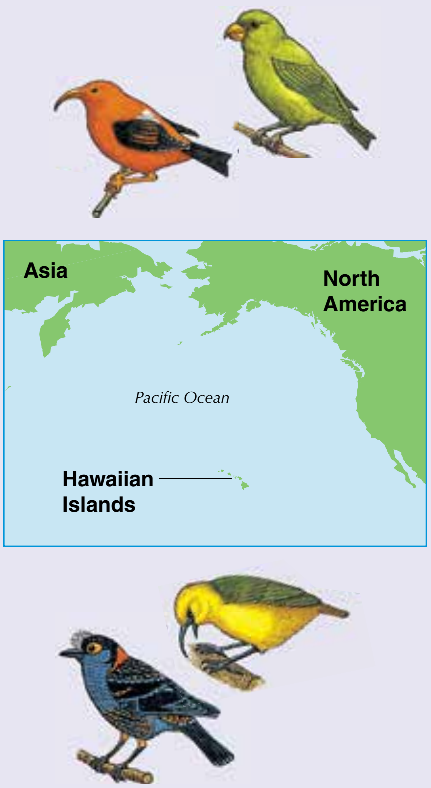
    Provide a reason for your response.







13. Honeycreepers are found only in the Hawaiian Islands and share a common ancestry. Examples of four species of honeycreepers are shown in the figure below.
    (a) Suggest reasons for their different appearance.
    (b) Share your suggestions with others.
    (c) Create a story to explain how and why these honeycreepers look so different.



12.8 Where is the evidence?

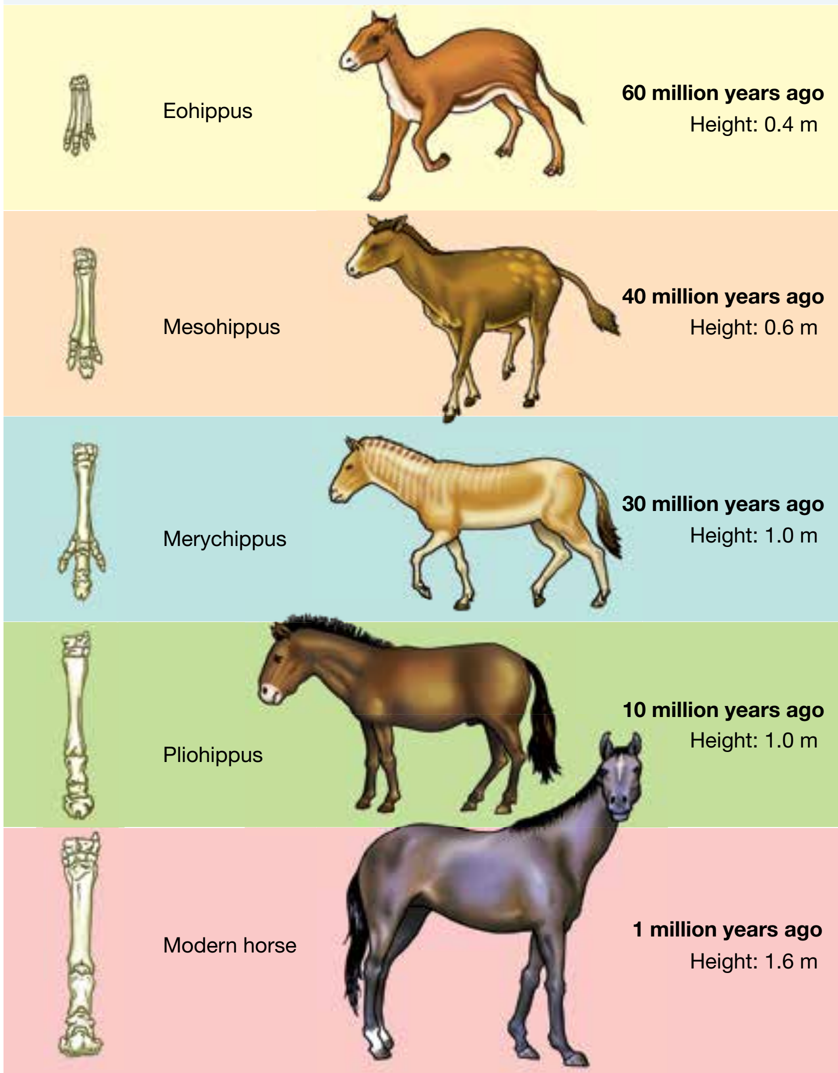
Darwin and Wallace based their theory of evolution by natural selection on many observations, including those made while travelling around the globe. Since then a great deal more evidence that provides further support for the theory of evolution has been uncovered.

12.8.1 The fossil record

As outlined in subtopics 12.3 and 12.4, the fossil record supports the theory of evolution by natural selection. It does this in a number of ways. The fossil record shows that the organisms living on Earth have become increasingly complex over time, and that some species that used to live on Earth have now become extinct. There is also fossil evidence of gradual change occurring in particular groups of organisms. For instance, fossils of ancient horse species have been found. They indicate that over the last 60 million years horses have become taller, their teeth have become adapted for grazing rather than eating soft leaves and fruit, and their feet have changed from having spread out toes to having a single hoof. The horses of 60 million years ago were ideally suited to the environment in which they lived: forests where they could feed on fruit and leaves and where their spread out toes and small size would have made it easier to walk on soft ground and remain inconspicuous. Over time the forests were replaced by open plains. Teeth suited for eating tough grasses became advantageous. Long legs and hoofs gave horses a better chance of getting away from predators.

Fossils that show the transition between two groups of organisms have also been found. Such fossils are called transitional forms. The fossilised remains of *Archaeopteryx* show bird-like features including wings with feathers, but they also show reptilian features including teeth and a long bony tail. This supports the idea that birds evolved from dinosaurs.

The evolution of the horse



Archaeopteryx fossil

12.8.2 Comparative anatomy

Comparative anatomy involves comparing the structural features of different species or groups of animals. The forearms of mammals, amphibians, reptiles and birds are remarkably similar in structure. Each, however, is used for a different function, such as swimming, walking or flying. The structure of the forearm can be traced back to the fin of a fossilised fish from which amphibians are thought to have evolved.

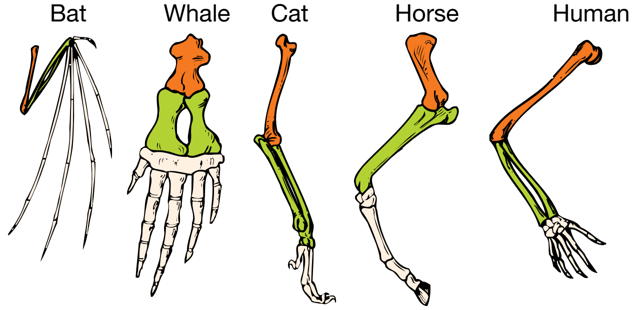
Similarity in characteristics that result from common ancestry is known as **homology**. Anatomical signs of evolution such as the similar forearms of mammals are called **homologous structures**. In the diagram top right, you can see that each limb has a similar number of bones that are arranged in the same basic pattern. Even though their functions may be different, the similarity of basic structure still exists.

Homologous structures should not be confused with analogous structures. Unrelated species living in similar environments (with similar selection pressures) in different parts of the world often have similar structures. This is an example of convergent evolution. The fins of a dolphin and a shark, or the wings of a bat and a butterfly, are analogous structures: they perform the same role but have different evolutionary origins.

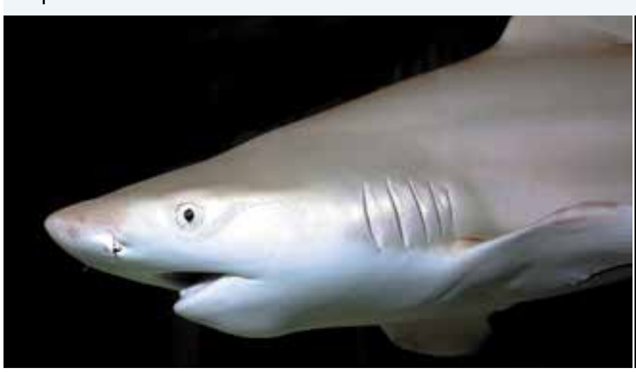
12.8.3 Comparative embryology

Organisms that go through similar stages in their embryonic development are believed to be closely related. During the early stages of development, the human embryo and the embryos of other animals appear to be quite similar. The embryos of fish, amphibians, reptiles, birds and mammals

The structures shown have the same basic structure since they are all derived from a vertebrate forelimb. Do they have identical functions?



Gill slits are visible in sharks, but in bony fish they are concealed beneath a scaly panel known as an operculum.

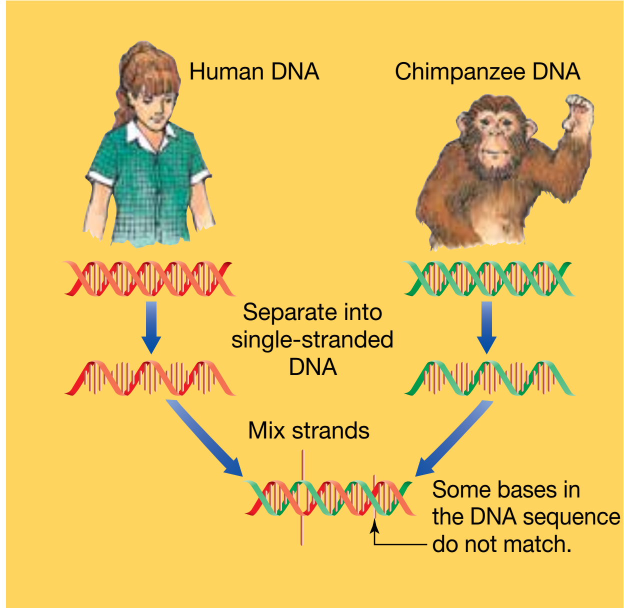


all initially have gill slits. As the embryos develop further, the gill slits disappear in all but fish. It is thought that gill slits were a characteristic that all these animals once shared with a common ancestor.

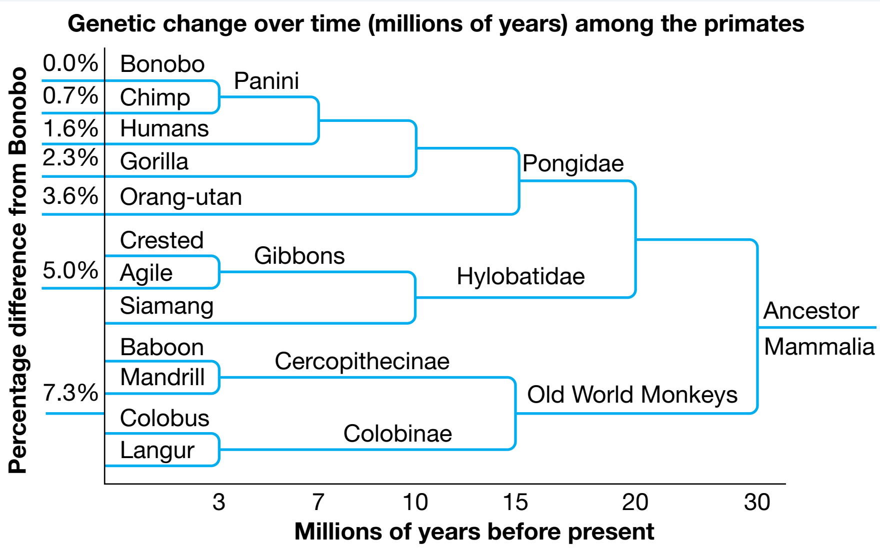
12.8.4 Molecular biology

The evolutionary relationships among species can also be reflected in their DNA and proteins. The closer the match in the DNA sequences, the more recent their common ancestor and hence the more closely they are related. You are more closely related to your brothers or sisters than to your cousins, who in turn are more closely related to you than your classmates. So your DNA is more similar to your siblings' DNA than to your cousins' DNA. Likewise, humans and chimpanzees have very similar DNA, compared to that of humans and ferns. **DNA hybridisation** is a technique that can be used to compare the DNA in different species to determine how closely related they are.

DNA hybridisation. The more closely related organisms are, the more similar are their DNA sequences.



Differences in DNA sequence can give an idea of how long two species have been separated.



HOW ABOUT THAT!

Whales, seals and manatees are all aquatic mammals with similar body shapes. It would seem sensible to hypothesise that they are all descendants of the same aquatic mammal. DNA evidence has revealed otherwise. Seals are more closely related to dogs than they are to whales or manatees. Whale DNA is similar to cow DNA and manatee DNA is a close match to elephant DNA. So it seems that there have been at least three separate instances in the evolution of life where mammals have returned to the water. The body shape of whales, seals and manatees is an adaptation to their aquatic environment rather than the result of recent common ancestry.

12.8 Exercise: Remember and think

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Remember

1. Match each of the words in the table below with its meaning.

Word	Meaning
(a) *Archaeopteryx*	(i) Structures that perform the same role but have different evolutionary origins
(b) Convergent evolution	(ii) Comparing the structure of organisms
(c) Transitional forms	(iii) The tendency of unrelated organisms living in similar environments to acquire similar structures
(d) Analogous structures	(iv) A fossil that supports the idea that birds evolved from reptiles
(e) Comparative anatomy	(v) A technique used to compare the DNA of organisms
(f) DNA hybridisation	(vi) A fossil that displays features from two distinct groups of organisms

2. **Outline** four pieces of evidence that support the theory of evolution.
3. **Describe** the basic structure of the limbs of vertebrates.

Think

4. **Examine** the diagram showing the evolution of the horse.
   (a) **Describe** how horses have evolved over the last 60 million years.
   (b) What type of horse would have been 'fittest' (in terms of biological fitness) 60 million years ago? **Explain** your answer.
   (c) What type of horse would have been fittest one million years ago? **Explain** your answer.
   (d) Horse breeders pay large sums of money to have prize-winning racehorses breed with the mares in their stables. The fastest horses are flown around the world for breeding purposes. It is also possible to collect and freeze sperm from successful racehorses. This sperm can be used to impregnate many mares. **Explain** how this might impact on the evolution of the horse. How might horses look in another million years?

Skill builder

5. Study the figure showing differences in DNA sequences.
   (a) You might have heard people say that humans 'are descendants of chimpanzees'. Is this actually correct according to the figure? What is a more accurate way of describing the evolutionary relationship between humans and chimps?
   (b) Which of the species shown in the diagram is most closely related to bonobos?
   (c) How long ago did the common ancestor of humans and chimps exist?
   (d) According to this diagram, are humans most closely related to chimps or gorillas? **Explain** your answer.
   (e) Are baboons most closely related to langurs or orang-utans? **Explain** your answer.

Investigate

6. Use an image search engine to locate pictures of fossilised transitional forms. Cut and paste them into a word document. Next to each picture write down the name of the fossil and **explain** how it supports the theory of evolution.
7. Use the **Whale kiosk** weblink in the Resources tab to work through an interactive on whale evolution. After using the interactive write a brief report that **outlines** how DNA evidence can be used to work out evolutionary relationships between organisms.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Whale kiosk

Complete this digital doc: Worksheet 12.6: Evidence for evolution (doc-12820)

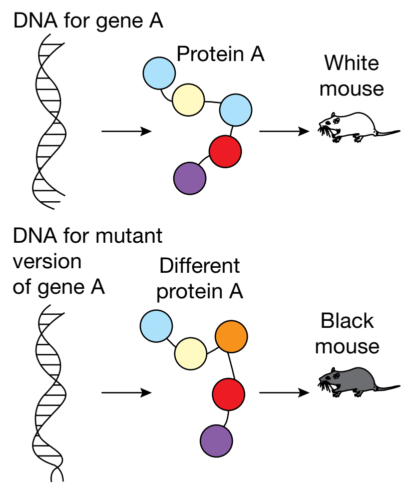
12.9 It's all about genes

Science as a human endeavour

12.9.1 Inheritance and variation

When Darwin and Wallace proposed that evolution occurred through natural selection little was known about the way in which characteristics could be inherited. Today we understand that favourable variations are transmitted through genes.

Gregor Mendel — the monk who carried out breeding experiments on peas — was a contemporary of Charles Darwin and Alfred Wallace, but it is quite likely that Darwin never read Mendel's work (although Mendel did read Darwin's *On the Origin of Species*; a copy of the German translation of Darwin's work annotated in Mendel's handwriting is evidence of this). The first edition of Darwin's *On the Origin of Species* was published in 1859. It was some time later, in the early 1900s that the role of chromosomes in the inheritance of characteristics was first understood. It was not until 1953 that the structure of DNA was described. Importantly though, as new knowledge about genetics and the inheritance of characteristics has been discovered it has helped to make sense of the way evolution occurs.



The reason that certain characteristics can be passed on to the next generation is because these characteristics are determined by our genes. Many of the variations between members of a species are the result of differences in their DNA. The frog that camouflages better amongst the rocks has DNA sequences that code for the production of proteins that, through their action, result in the frog having a particular pattern on its skin. The cells of the seal that grows larger and is thus able to outcompete other seals for territory and mates contain DNA that codes for the proteins that regulate growth, such as growth hormone. A kangaroo that has white fur (an albino kangaroo) has a faulty copy of the gene that codes for the protein that controls hair and fur colour. This variation is detrimental. The kangaroo is less likely to survive to adulthood and produce many offspring than kangaroos of normal colouring because its white fur and skin make it more vulnerable to sunburn and skin cancer, and more visible to predators.

An albino kangaroo

12.9.2 Genetic diversity

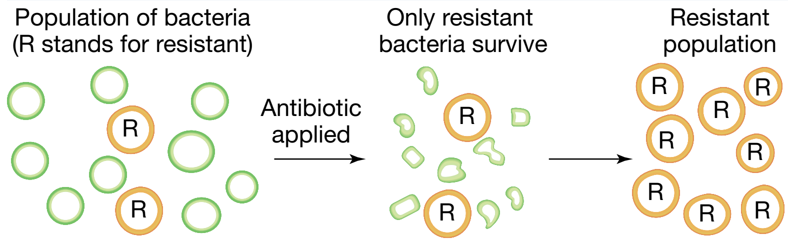
Biological diversity or biodiversity means variety amongst living organisms. Biodiversity exists at the ecosystem, species and gene level. Biodiversity at the gene level is important to evolution. In order for evolution to occur, there must be genetic differences between the members of a species, so that some organisms will be more successful than others. If all the organisms belonging to one species were genetically and physically identical, then they would all be either highly successful or they would all die rapidly in a particular environment. Biodiversity at the gene level is also important for the long-term survival of a species. A particular genetic make-up may be very successful at a certain time in Earth's history. If the environment begins to change, however, this genetic make-up may no longer be successful. Genetic diversity plays a role in safeguarding a species from extinction when the environment changes.

What causes diversity?

When organisms reproduce asexually, the DNA in their cells is copied exactly from one generation to the next, unless a mutation occurs. For instance, bacteria reproduce by binary fission to produce genetically identical bacteria. Plants grown from bulbs, tubers or runners are genetically identical to the parent plant. In asexual reproduction, mutations are the main source of genetic diversity. A mutation is an error that occurs when the DNA is copied during cell division. Mutations can produce new alleles. Some mutations are detrimental (harmful) to organisms. A mutation that prevents mould from making a particular vitamin it needs to survive is an example of detrimental mutation.

Most mutations have neither a positive nor a negative impact on the survival of the organism. Occasionally though, mutations increase an organism's chance of survival. A mutation might make bacteria resistant to penicillin. In a patient taking penicillin to treat a bacterial infection the bacteria that have a copy of the section of mutant DNA that codes for penicillin resistance will survive while the other bacteria will be killed by the penicillin. The surviving bacteria will have little competition for food and other resources. They will multiply and pass on the penicillin resistance gene to their offspring. This process will be repeated over a number of generations and over time the proportion of penicillin resistant bacteria will increase.

The widespread use of drugs is leading to bacteria evolving antibiotic resistance at a rapid rate. If a small proportion of bacteria survive antibiotic treatment and multiply, over generations resistant bacteria will become more prevalent and the bacterial population will become less susceptible to the antibiotic.



Organisms that reproduce sexually have additional sources of genetic variation. Sexual reproduction involves the combining of a male and female gamete — an egg and sperm in humans. The male and female gametes are produced by meiosis. In topic 11 we saw that meiosis can produce gametes containing many different combinations of alleles. A human male can produce sperm cells containing millions of different possible combinations of alleles. The chance of any two eggs from the same female or two sperm cells from the same male containing exactly the same genetic code is very small. At fertilisation, gametes produced by two different individuals (a male and a female) combine. This is also a source of variation.

12.9.3 Human impact on evolution

Artificial selection is one way that humans are bringing about changes in species that are not the result of natural selection. Artificial selection is also causing a reduction in the genetic diversity of certain species. For thousands of years we have bred domestic animals and plants to suit our needs by selective breeding. Early humans chose to breed dogs that were loyal, fast and good at retrieving game, and so hunting dogs evolved to have these traits. This is called **artificial selection**. In domestic species, valuable characteristics such as high milk yield in dairy cattle, or abundant, sweet fruit in apples have been the result of artificial selection.

The Chihuahua, the world's smallest dog, weighs 12 kg and grows to around 20 cm. Because of its breeding, the Chihuahua is susceptible to slipped stifles (a knee injury caused by joint weakness) and fractures, and may also suffer from jawbone disorders, eye problems, heart disease, and tooth and gum complaints. Many purebred animals would be unable to survive in the wild, where they would be susceptible to predators.

Artificial selection results in reduced genetic diversity because fewer individuals are chosen for breeding. This results in **inbreeding**. If the individuals chosen for breeding have any disease-causing alleles, then inbreeding results in these becoming more common. Inbreeding has to be carefully managed in zoo breeding programs, in purebred show animal breeds, and it may be an issue in natural populations that are small; for example, in endangered species.

Inbreeding in agricultural strains is also a concern. In a wild population of wheat, different wheat plants have different levels of resistance to a wide range of disease; so if disease strikes, some individual plants will survive. Modern agriculture tends to rely on genetically identical strains (in some cases, genetically modified). This makes many cultivated species more vulnerable to new disease, which could wipe out all plants in one go.

Reproductive technologies and evolution

In topic 2 we learned about reproductive technologies, including artificial insemination, in-vitro fertilisation (IVF) and cloning. These technologies, particularly if they are used in agriculture or to breed pedigree animals, give humans further opportunity to select exactly which characteristics will be passed on to the next generation. This is another way that humans interfere with the process of natural selection, and it can impact on biodiversity.

Artificial insemination has the potential to reduce biodiversity. Sperm from one prize-winning bull can be frozen, flown all around the world and used to inseminate hundreds of cows, thus passing on the genetic characteristics of that particular bull to a much greater proportion of the next generation than would have been otherwise possible.

When IVF is used, it is possible to test the embryos prior to implantation for certain genetic characteristics. Imagine that IVF was used to produce sheep embryos, and that it was possible to test these embryos to find out if they carry an allele that gives them faster growing wool. It would be possible to implant only the embryos carrying this gene into the uterus of a ewe, reducing genetic diversity.

Cloning also has the potential to impact on diversity. Cloning produces animals that are genetically identical to their parent. As cloning methods improve, it may one day become possible to produce hundreds of horses that are genetically identical to last year's Melbourne Cup winner.

Recombinant DNA technology can be used to cut and paste desirable genes from one organism's genetic code into another's. If the same desirable genes are cut and pasted into all organisms, genetic diversity will be further reduced.

There are concerns that the reduction in genetic diversity within the strains of plants and animals used in agriculture might put them at higher risk of being wiped out by disease or other environmental changes. Some crops species, particularly plants that are propagated from cuttings, bulbs or suckers, show very little variation. A change in environmental conditions (e.g. more extreme temperatures due to global warming), or a new disease could completely wipe out these species. Genetic diversity would increase the chance of at least some members of the species surviving to reproduce and pass on the genes to the next generation that allowed them to survive the change in the environment.

12.9 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Write a sentence that includes the following words: DNA, variations, genes, evolution.
2. **Define** the following terms: 'biodiversity', 'artificial selection', 'inbreeding', 'mutation'.
3. **Identify** some characteristics that early humans selected when breeding dogs.
4. **Identify** three situations in which inbreeding may occur.
5. **Outline** the advantages antibiotics have over previous methods of treatment for bacterial infections.
6. **Identify** the source of genetic variation in organisms that reproduce asexually.

Think

7. Many genetic disorders are recessive. The symptoms of the disease will not show up unless a copy of the faulty allele is inherited from both parents.
   (a) Use your knowledge of the theory of evolution by natural selection to explain why genetic disorders that cause early death are rarely dominant. Why would the allele for such a disease be unlikely to become common in a population?

(b) Tay-Sachs is a recessive genetic disorder. Symptoms usually begin to appear around 6 months of age and most children affected by the disorder die by the age of 4. Explain why the allele for Tay-Sachs has not disappeared from the gene pool.

8. **Outline** how selective breeding techniques could be used to produce cats with very long hair and large ears.
9. **Explain** why agriculture often uses genetically identical strains instead of those with a range of characteristics.
10. A 2006 study showed that because Australia had banned the use in livestock of one particular group of new antibiotics (the fluoroquinolones) the level of resistance by bacteria to a similar human antibiotic called cyprofloxacin was only 2%. In countries where fluoroquinolones in livestock are used, the resistance level is around 15%. **Explain** these findings.
11. Most large-scale commercial banana farmers grow a type of banana called the cavendish banana. These bananas are seedless and the banana plants are grown from suckers (a form of asexual reproduction).
    (a) **Explain** why there is little biodiversity among cavendish banana plants.
    (b) In some countries, crops of cavendish bananas have been destroyed by a type of mould. There are fears that the cavendish banana may become extinct within the next 10 years. **Explain** why the risk of extinction would be lessened if there was more genetic variation in this species of banana.
    (c) **Propose** how genetic engineering could be used to prevent the extinction of the cavendish banana.

Investigate

12. A shar-pei dog is pictured at right.
    (a) **Investigate** the health problems that are common in this breed of dog.
    (b) **Discuss** whether the sale of dog breeds such as the shar-pei should be banned.

12.10 Project: Natural Selection — the board game!

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12.10.1 Scenario

There are few people in Australia today who haven't played a board game such as *Monopoly, Scrabble* or *Civilisation* sometime in their life. Even today, when computer games such as *Halo* or online games such as *World of Warcraft* are regularly played by tens of thousands of Australians, sales of old-school board games such as *Snakes and Ladders, Kingmaker* and, yes, *Monopoly* are still a healthy component of the income for a toy and game store. Apart from the fact that they are a great choice when there's no electricity and they can be played and enjoyed by people from completely different generations, psychologists suggest that their continued popularity can also be attributed to the fact that there is just as much luck as skill that determines the winner. In this way, board games are much like real life!

The effectiveness of using game play as a way of teaching concepts is the stock in trade of the educational game company BrainGames, who produce computer games that teach science, maths, history and geography concepts. Games such as *The Revenge of Pavlov's Dogs* and *Where in the World is Amerigo Vespucci?* have made them the leader in the educational games market. However, keen to exploit the non-computer-equipped market sector, BrainGames now want to branch out into board games and the first board game they want to produce will be based on one of the key ideas of biology.

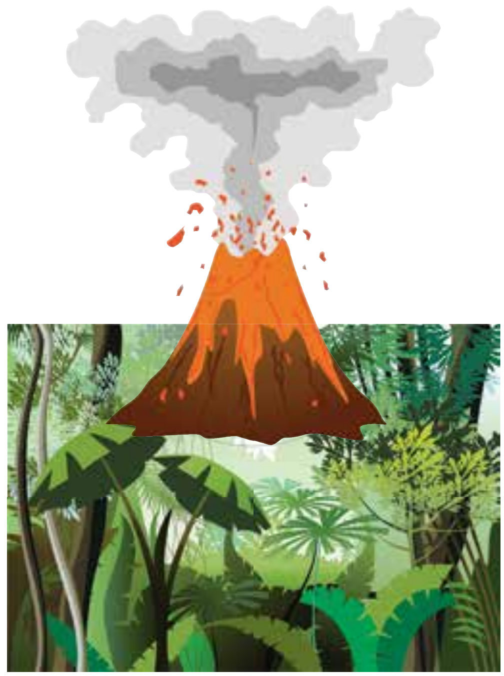
12.10.2 Your task

As part of the Games Development Division at BrainGames, you and your team are to develop a prototype board game based on the idea of natural selection and evolution. In this game, players will be able to select a variety of characteristics to give an organism and then, over the course of the game, see whether these organisms survive intact as their environment is changed. Your prototype must include:

- a game board
- game pieces
- a rule book.

You may also choose to include game mechanics such as cards, spinners or dice.

12.10.3 Process



- Start your research. Make notes of information you discover that will assist you in your design. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about how natural selection works to influence the survival and adaptation of organisms in a particular environment over time. You may also include notes and ideas for different aspects of your game.
- Use your research to come up with a board game design.
- Download the sample rule book from your Resources tab. Using this as a model, create the rule book for your board game. It should cover the contents of the game box, how to set the game up to start, how each player's turn

is completed, what players have to do to win and so on. Keep in mind that the rules should be clearly written and easily understood by the players.
- Build a simplified version of your game and test its playability. Add or remove aspects of the game until you are happy with the way it works. Only then should you work on your final prototype.

12.11 Review

12.11.1 Fossils

- **define** the term 'fossil' — 12.2
- **outline** the conditions necessary for living things to fossilise — 12.2
- **distinguish** between the following types of fossils: 'moulds', 'casts', 'amber fossil', 'petrified fossils', 'carbon imprint' — 12.2
- **distinguish** between relative and absolute dating of fossils — 12.4
- **deduce** the relative age of fossils — 12.4

12.11.2 The history of life on earth

- **explain** radiometric dating — 12.4
- **extract** information from diagrams and tables relating to the history of life on Earth — 12.3
- **construct** a timeline for the history of life on Earth — 12.3
- sequence the major events in the evolution of life on Earth — 12.3

12.11.3 The theory of evolution by natural selection

- **define** the terms 'evolution', 'biological fitness' and 'natural selection' — 12.6
- **justify** why Lamarck's proposed mechanism for evolution was first considered then rejected — 12.5
- **outline** Darwin and Wallace's contribution to the theory of evolution — 12.5
- **explain** how new species evolve — 12.7
- **describe** the process of natural selection using examples — 12.6, 12.9
- **explain** the importance of variations in the process of evolution — 12.6, 12.9

12.11.4 Evidence supporting the theory of evolution

- **describe** how the fossil record provides evidence for evolution — 12.2, 12.4, 12.8
- **define** the term 'transitional form' and explain how transitional form supports the theory of evolution — 12.8
- **outline** how comparative anatomy and comparative embryology have been used to support the theory of evolution and to determine evolutionary relationships between species — 12.8
- **describe** examples of molecular biology techniques and how they are used to work out evolutionary relationships — 12.8

12.11.5 Evolution and genes

- **assess** the importance of biodiversity to the long-term survival of species — **12.9**
- **outline** some sources of genetic diversity in species that reproduce asexually and sexually — **12.9**
- **describe** the potential impact of reproductive technologies and genetic engineering on genetic diversity — **12.9**

Individual pathways

ACTIVITY 12.1	ACTIVITY 12.2	ACTIVITY 12.3
Revising evolution doc-10675	Investigating evolution doc-10676	Investigating evolution further doc-10677

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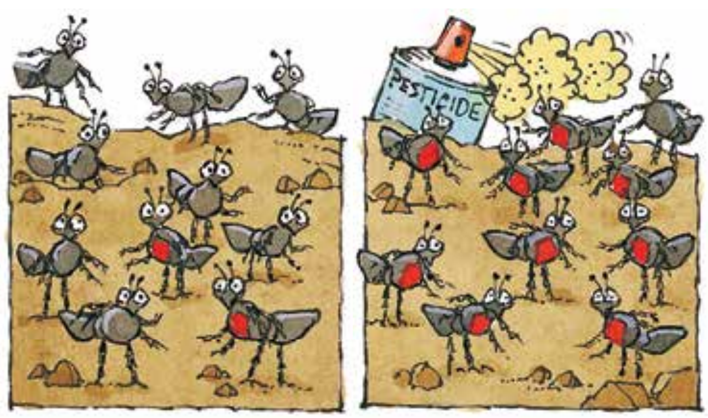
FOCUS ACTIVITY

Option 1

When the insecticide DDT was first used it was highly effective at killing most insects. Now many insects are resistant to DDT. Use a series of diagrams similar to those at right to **explain** how an insecticide such as DDT can act as a selecting agent and result in an increase in the proportion of insects that are resistant to the insecticide over time. Include captions under each diagram.



Option 2

Koalas are found along the eastern coast of Australia. Koalas found in the southern, cooler part of the east coast are larger and have longer, thicker fur. The fur on their back is darker. Queensland koalas are smaller and have shorter, lighter and thinner fur. There is a gradual change in the size and fur type of the koalas from the south to the north of the east coast of Australia. This is an example of a cline (a cline is a gradual change in a trait across a species' geographical range).

Create a PowerPoint presentation that includes the following information:

(a) labelled photos illustrating the variations in koalas along the east coast of Australia
(b) one or more slides that explain why each type of koala is best suited to its environment
(c) a slide hat outlines how two or more separate species of koalas might arise over time
(d) slides tthat describe other examples of clines. Include photos.

Option 3

Design a picture book, suitable for students in stage 1 (years 1 and 2) about the evolution of life on Earth and the order in which different groups of living things evolved.

Access more details about focus activities for this topic in the Resources tab (doc-10674).

12.11 Review 1: Looking back

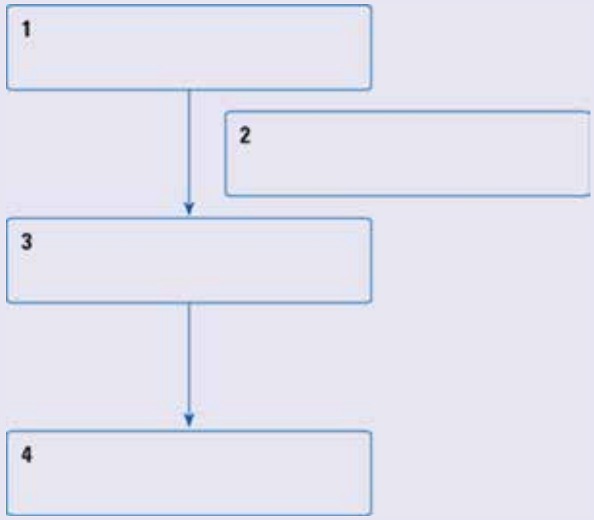
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Match the words below with their meaning.

Words	Meanings
(a) Mould fossil	(i) A species from which two or more species have evolved
(b) Cast fossil	(ii) A period in Earth's history during which dinosaurs roamed
(c) Radiometric dating	(iii) Diversity among organisms at the ecosystem, species and gene level
(d) Cainozoic	(iv) The present era
(e) Jurassic	(v) A technique used to determine the age of fossils and rocks
(f) Variations	(vi) Fossil where the shape of the organism is hollowed out in rock
(g) Biodiversity	(vii) When organisms with favourable characteristics are crossed with the aim of producing offspring with the same characteristics
(h) Common ancestor	(viii) The study of variation in living things in relation to geographical regions
(i) Natural selection	(xiv) A mechanism for evolution
(j) Artificial selection	(x) Differences
(k) Biogeography	(xi) Fossil where the shape of the organism protrudes out of the rock

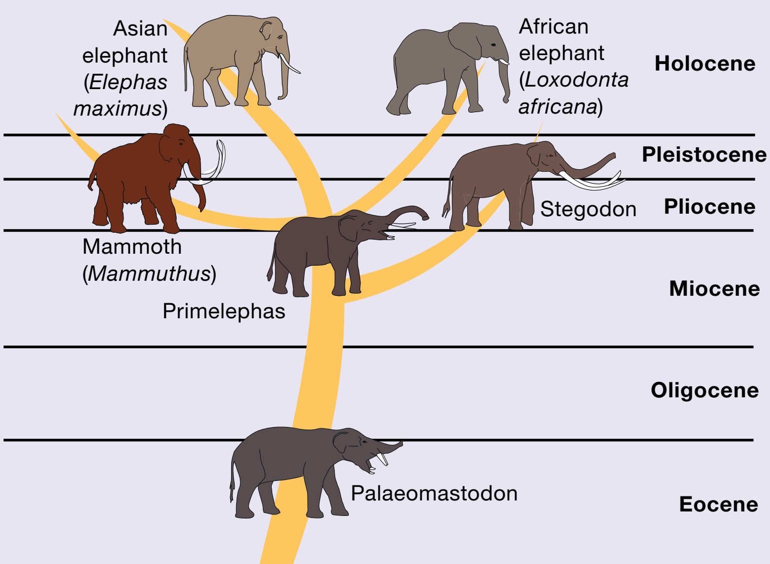
2. Use diagrams to **explain** how an organism might fossilise if it sank to the bottom of a lake and rapidly became covered by mud.
3. **Outline** Darwin and Wallace's main contribution to the theory of evolution.
4. Lamarck proposed a mechanism for evolution that was later rejected. **Contrast** Lamarck's and Darwin's mechanism for evolution.
5. Sequence the following into the correct evolutionary order:
   (a) flowering plants evolve
   (b) early dinosaurs evolve
   (c) mammals, flowering plants, insects, fish and birds dominate
   (d) bacteria evolve
   (e) all living things are in the ocean; massive increase in multicellular organisms
   (f) most dinosaurs become extinct
   (g) greatest mass extinction of all time
   (h) dinosaurs dominate the planet.
6. **Contrast** the terms 'homologous' and 'analogous structures' using examples.
7. **Explain** how the fossil record of the horse supports the theory of evolution.
8. What are transitional forms? How do they support the theory of evolution? **Explain** your answer using *archaeopteryx* as an example.
9. The flu is caused by a virus. During the 2009 outbreak of H1N1 flu ('swine' flu) most Australians that had symptoms of H1N1 flu were not prescribed the antiviral drug Tamiflu. It was prescribed only for those suffering severe symptoms, or people who were elderly or suffering from other health conditions. However, in some parts of the world, Tamiflu was prescribed a lot more widely. In some countries low doses of Tamiflu were prescribed for anyone living with a person infected with the H1N1 virus, even if they were not showing any symptoms themselves. The first case of Tamiflu resistant H1N1 was detected in one of these people. **Explain** why a virus is less likely to develop resistance to Tamiflu if the drug is reserved for special cases.

10. Insert the following labels in the diagram at right to produce a model of how natural selection brings about genetic change in a population.
    (i) selective agent acts
    (ii) next generation contains more of the favourable characteristic
    (iii) individuals best suited to the environment (fittest) survive and reproduce more successfully
    (iv) population contains genetically different individuals



Test yourself

1. Which of the following is not an example of a fossil?
    (A) An insect from the Jurassic period trapped in amber
    (B) A cast of a dinosaur footprint
    (C) Petrified wood
    (D) A sample of sandstone from the cretaceous period **(1 mark)**
2. Whales, bats, dogs and humans have a similar bone arrangement in their forelimb. How does this support the theory of evolution?
    (A) It suggests that whales, bats, dogs and humans evolved from a common ancestor with a similar bone arrangement to these mammals.
    (B) It suggests that bats, humans and dogs evolved from whales.
    (C) It suggests that bats, dogs and humans all evolved from chimpanzees.
    (D) It suggests that dogs are more closely related to humans than to bats. **(1 mark)**
3. The diagram below shows some of the evolutionary relationships of the elephant family. What is the most recent common ancestor of the Asian elephant and the mammoth?



    (A) Stegodon
    (B) Primelephas
    (C) Palaeomastodon
    (D) The African elephant **(1 mark)**
4. In which of the following situations is a dead animal most likely to become a fossil?
    (A) A desert
    (B) The bottom of a muddy lake
    (C) A mountain cliff
    (D) An open grassland **(1 mark)**

5. Biologists make inferences about evolutionary relationships based on comparative anatomy. Molecular biology techniques such as DNA hybridisation and protein sequences may support or contradict these inferences. **Explain** how molecular biology techniques can be used to work out evolutionary relationships. **(3 marks)**
6. When Darwin visited the Galapagos Islands he found that longer beaked species of finches were found in areas where insects were plentiful and shorter beaked species were found where seeds were the main food source. **Account for** this observation using the theory of evolution by natural selection. **(3 marks)**

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Complete this digital doc: Worksheet 12.7: Life goes on: puzzle (doc-12821)

Complete this digital doc: Worksheet 12.8: Life goes on: summary (doc-12822)

TOPIC 13
Ecology

13.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

13.1.1 Why learn this?

Droughts, floods, bushfires! The Australian environment can certainly throw some nasty surprises. The cycle of years of droughts and bushfires followed by periods of heavy and prolonged rainfall is not new. The Australian continent was experiencing these extremes even before Europeans first arrived in Australia. Has the climate become even more extreme over recent times, though? How does this impact on animal and plant species?

Studying the way in which organisms interact with their environment and each other can help us appreciate the importance of preserving natural ecosystems. The loss of a species and other changes can have implications on the rest of the ecosystem. Increasingly, human activities are damaging the natural environment. Clean fresh water is in short supply in many parts of the world. Increasing levels of greenhouse gases are causing our planet to warm up, and rubbish is piling up at an alarming rate. The situation is not hopeless, however. Scientific knowledge and creative ideas are providing solutions to some challenging environmental problems.

LEARNING SEQUENCE

A kangaroo bouncing through flood waters

Ecological footprint

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

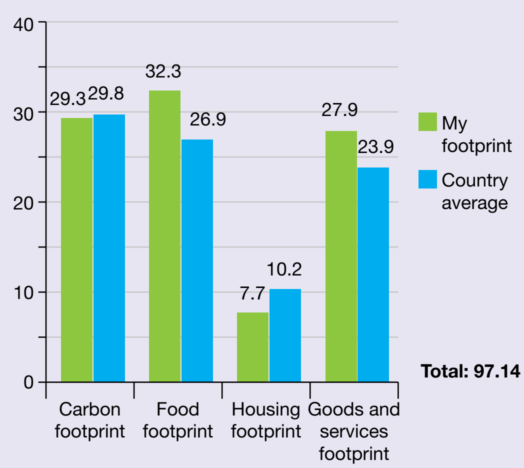
How much of an impact are you having on the environment? Your lifestyle can determine how much of our planet's resources you use. Your *ecological footprint* is a measurement of how much biological productive land is needed to support someone with your lifestyle. It helps you to see how much of an impact you have on our planet's resources.

What do you think may happen if the overall ecological footprint of our species is greater than our planet can provide us with? By understanding more about the ideas behind ecological footprints, we can empower people to take responsible personal and collective actions to support sustainable lifestyles.

How big is your footprint?

Thinking about ecology

1. **Define** the term 'ecological footprint'.
2. Why is it important to understand the ideas behind ecological footprints?
3. Use the **My footprint** weblink in the Resources tab and take a quiz to find out what your ecological footprint is. Use the links provided at the end of the quiz to find out some ways in which you could change your lifestyle to reduce your ecological footprint.
4. Charlotte completed an ecological footprint quiz. Her results are shown below.
   (a) **Explain** the statement 'if everyone on the planet lived my lifestyle, we would need 6.18 Earths'.
   (b) Overall, is Charlotte's footprint bigger or smaller than the average Australian?
   (c) Suggest some ways that Charlotte could reduce her food and goods and services footprint.
   (d) People living in wealthy countries such as Australia and the US have, on average, a much bigger ecological footprint than people living in poor countries. **Explain** why.
   (e) Some airline companies now offer carbon offsets when passengers book flights. Find out what carbon offsets are. **Discuss** whether they are a good way for frequent fliers to reduce their ecological footprint.



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Explore more with this weblink: Ecological footprint

13.2 Features of the local ecosystem

13.2.1 Going out in the field

The first step in conserving our environment is to find out as much as we can about it. That involves going out into the field, making observations and taking measurements. Observing organisms in their natural habitat provides information about the way in which they interact with each other and their surroundings. Measuring abiotic factors such as temperature and soil pH can help us understand why some species thrive and others wither in a particular environment.

Field work is an important component of Ecology. It involves visiting natural environments and collecting data about the type of animals, plants and other organisms found there. Researchers are sometimes fortunate to be able to observe interactions between different species or between an organism and its environment first hand. They might observe a kookaburra feeding on a lizard, or an elk fern growing on a fig tree and using it for support. Some relationships have to be inferred. An animal's faeces (poo) can provide clues about its diet. Animals may be tagged and tracked. Cameras that trigger when movement is detected are useful to capture behaviours that may otherwise be missed.

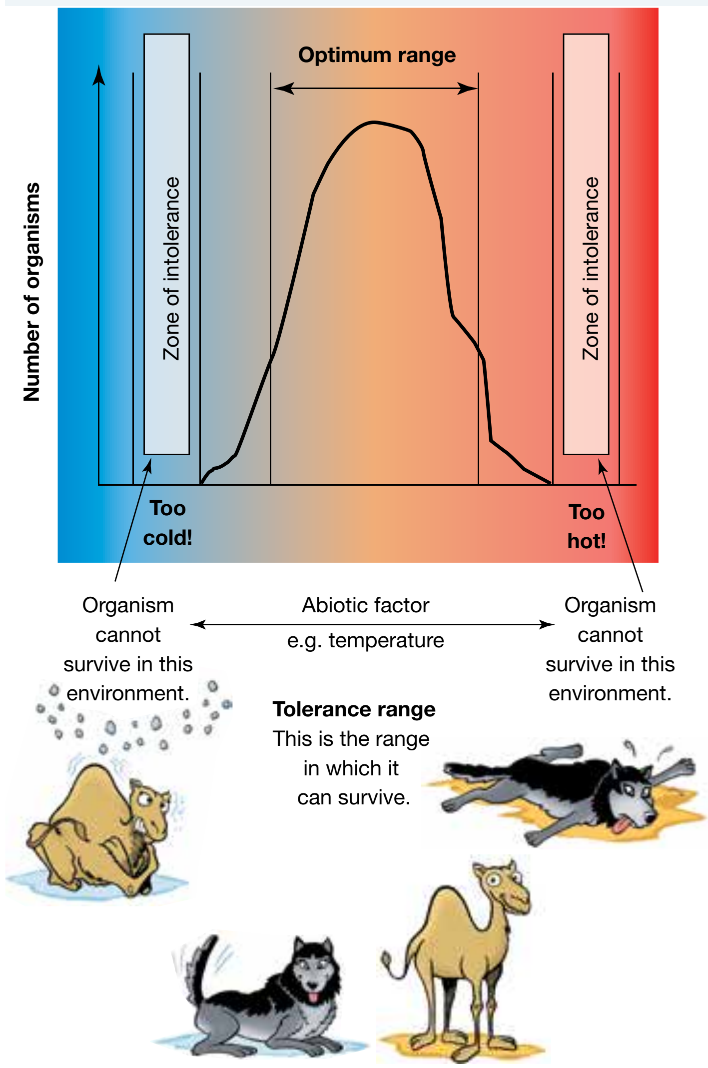
13.2.2 Measuring abiotic factors

Abiotic factors are the non-living characteristics of an ecosystem. They include light intensity, temperature, the type of soil, the availability of water, the amount of salt and nutrients in the soil, wind speed and soil pH. Abiotic factors determine the type of organisms that can survive in a particular environment.

For example, most species can survive only within a narrow temperature range. Emperor penguins can tolerate temperature well below zero but would die if the temperature reached

Elk ferns do not grow on the forest floor, they grow high up in the branches of other trees. This allows them to obtain light needed for photosynthesis.

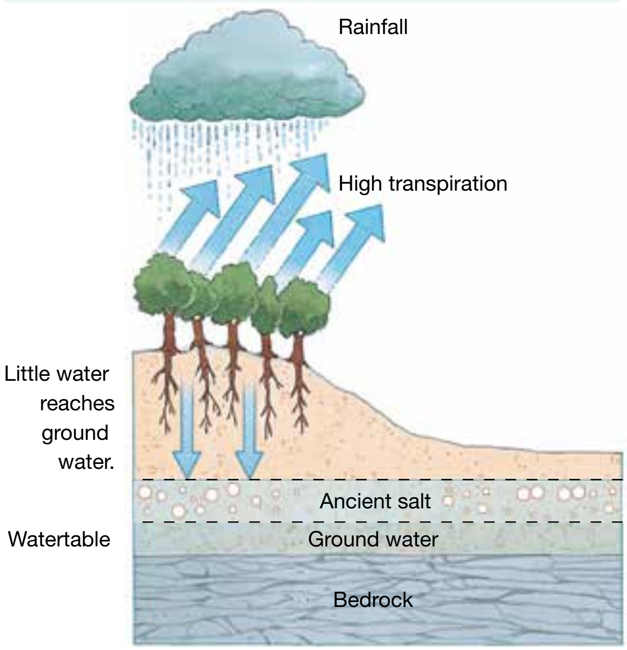
Each species tolerates a certain range of temperatures.



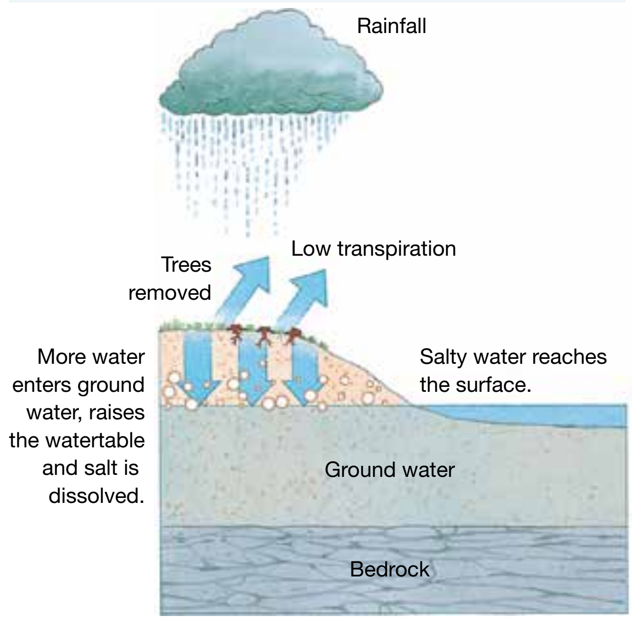
40 degrees. Humans would not fare well at temperatures below zero without many layers of clothing. Each species has a tolerance range for each abiotic factor. The optimum range is the range within the tolerance range in which it functions best.

Salinity is another factor that determines the type of plants that can grow in an area. Many plants cannot tolerate high levels of salt in the soil. This is a problem in parts of Australia where the ground water (water below the Earth's surface) is very salty. Normally the roots of most plants do not reach the ground water, so plants growing above salty ground water are not affected. Removing large trees and replacing them with crops that have shallow roots and irrigation are two factors that can cause the ground water to rise closer to the surface, killing the plants.

Trees with deep roots take up water from the soil. The watertable remains below the root area of the plants.



Once trees have been removed, little water is taken up by plants. The watertable rises and reaches the surface.



Land that is near the ocean is flooded by sea water twice a day due to the action of tides. Soil salinity levels are thus naturally high. Only certain plants, including mangroves, can tolerate such high salt levels. There are different species of mangrove and they cope with the extreme salinity in a variety of ways. Some secrete salt via glands in their leaves, others store the excess salt in leaves that are eventually shed and some prevent the salt from entering their roots.

INVESTIGATION 13.1

Measuring abiotic factors

AIM: To measure some abiotic factors for two environments

You will need:

access to a natural area in your school grounds or bushland near your school with a stream, pond or other body of water
a data logger with temperature probe and light probe or a thermometer and hand-held light sensor
wind vane
wet–dry thermometer (or humidity probe for data logger)
dropper bottle of universal indicator solution

universal indicator colour chart
calcium sulfate powder
water in a small wash bottle
thermometer
dropper bottle of silver nitrate solution (0.1 mol/L)
Petri dish
sun hat and sunscreen

CAUTION: be sun smart!

- Break into groups. Each group will need to study a different area of the environment. Try to choose areas that are different. Choose an area where water is available so you can collect a sample.
- Copy the table below into your notebook. Fill in the missing pieces of equipment in the second column.

Discussion

1. Use the equipment available at your school to measure the abiotic factors listed in the table. Complete the third column of the table.
2. When you are back in the classroom, construct a table or spreadsheet to enter the results collected from each group. Calculate the average reading for each abiotic factor measured.
3. Choose one of the abiotic factors you measured and construct a column graph showing the reading for each location studied.
4. pH is a measure of the acidity or alkalinity of a substance. A pH less than 7 is considered acidic. The lower the pH the more acidic the sample is.
   (a) Which water sample was most acidic?
   (b) Which soil sample was most acidic?
5. Identify any trends in the results you obtained. For example, how did the results for sunny areas compare with those for shady areas?
6. Which of the above tests were qualitative and which were quantitative?
7. Which variables were controlled in the salinity test (the test where silver nitrate was added to the water samples)?
8. Suggest how the water salinity test could be modified to compare the salinity of soil samples A and B. (*Hint:* You may need to add water to the soil and filter the mixture.)

<table>
<tr><th>Abiotic factor</th><th>Equipment used and/or method</th><th>Measurement</th></tr>
<tr><td>Temperature</td><td></td><td></td></tr>
<tr><td>Air humidity</td><td>Wet–dry thermometer</td><td></td></tr>
<tr><td>Light intensity</td><td></td><td></td></tr>
<tr><td>Soil humidity</td><td>Soil humidity probe (if available)</td><td></td></tr>
<tr><td>Soil pH</td><td>Collect a small sample of soil in the Petri dish and make it into a paste by adding water from the wash bottle. Sprinkle the moist soil with calcium sulfate powder then add drops of universal indicator over the white powder. Use the colour chart provided with the indicator to identify the pH of the soil.</td><td></td></tr>
<tr><td>Water pH</td><td>Place 5 mL of water sample A in a test tube. Add 3 drops of universal indicator. Compare the colour obtained to the colour chart provided and record the pH of the water sample. Repeat using water sample B.</td><td></td></tr>
<tr><td>Water salinity</td><td>Place 5 mL water collected from the site in a test tube. Add 3 drops of silver nitrate solution. Note whether the sample remains clear, becomes slightly cloudy or completely white/grey. Work out the salinity of the water sample using the following table.
<table><tr><th>Description</th><th>Salinity</th></tr><tr><td>Clear</td><td>Nil</td></tr><tr><td>Slightly cloudy</td><td>Low salinity</td></tr><tr><td>Completely white/grey</td><td>High salinity</td></tr></table>Repeat using tap water as a comparison.</td><td></td></tr>
</table>

13.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** 5 examples of abiotic factors.
2. **Distinguish** between the terms 'optimum range' and 'tolerance range', using temperature as an example.
3. **Define** the term salinity.
4. What type of substances have a low pH?

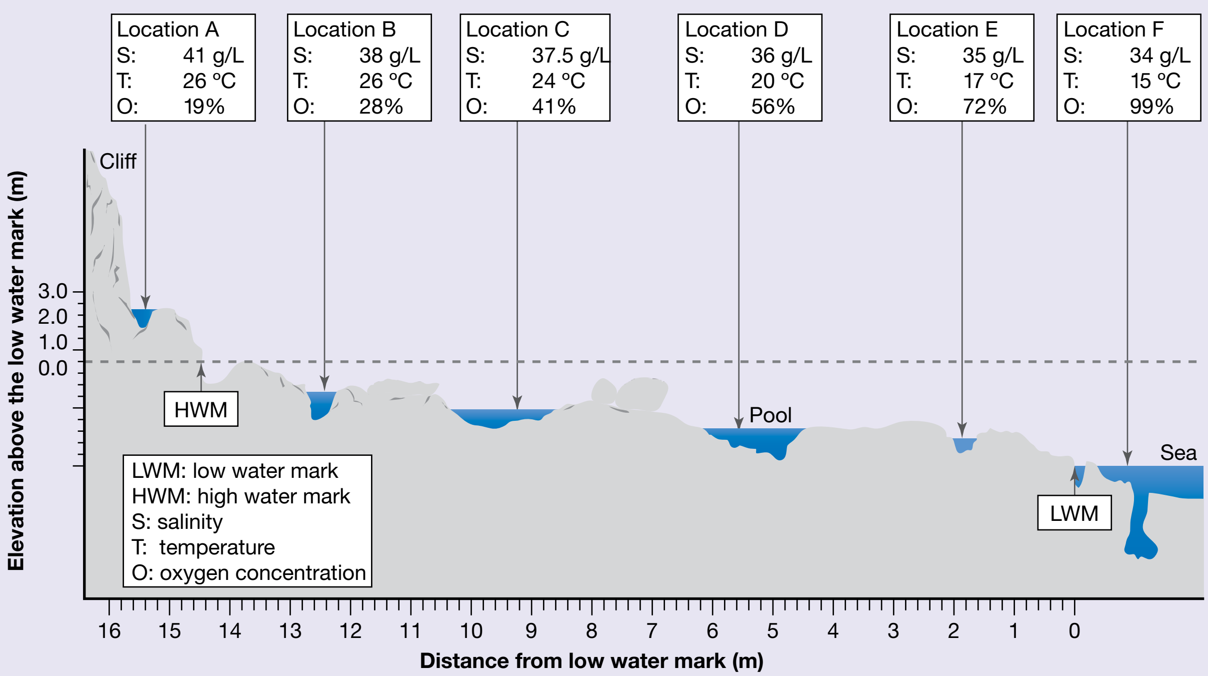
Think

5. **Explain** why it is important to observe animals in the field. What additional information might be provided by observing an animal in its natural environment rather than in a zoo?
6. Plants that grow high up in the branches of trees like the elk fern are called epiphytes. Suggest why epiphytes are mainly found in rainforests.
7. Study the diagram at right.
   (a) **Identify** 5 abiotic factors that may affect the health and chance of survival of the fish.
   (b) Apart from the fish, what other living things are present in the fish tank?
   (c) **Explain** how the plants and the bacteria in the gravel might play a part in keeping the fish alive.

Skill builder

8. The diagram below shows data collected by a group of students on a field trip.

Biozone International (Adapted from Biozone's Year 11 Biology Student Workbook (2012) 255).



(a) Copy and complete the table below. *Hint:* Take the middle of each rock pool as the distance from the low water mark.

Location	Distance from low water mark (m)	Salinity (g/L)	Temperature (°C)	Oxygen concentration (% saturation)
A	15.4	41	26	19
B				
C				
D				
E				
F				

(b) **Construct** the following graphs, either on graph paper or using Excel.
  (i) A line graph showing distance from the low water mark on the *x*-axis and salinity on the *y*-axis.
  (ii) A line graph showing distance from the low water mark on the *x*-axis and temperature on the *y*-axis.
  (iii) A line graph showing temperature on the *x*-axis and oxygen concentration on the *y*-axis.

(c) **Describe** the trend shown in each graph.

(d) The measurements were taken on a sunny spring day. **Explain** why the water in the pool that is furthest from the low tide mark contains water that is saltier and warmer than the pool closest to the low tide mark.

(e) **Explain** why many of the animals living in location F could not survive in location A.

Research

9. Use the **Salinity** weblink in the Resources tab to find out why salinity is a problem in the Murray–Darling Basin. Prepare a report including the following:
   - a map of Australia showing the location of the Murray–Darling Basin
   - some of the causes of the problem
   - what can be done to address the problem.

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Explore more with this weblink: Salinity

Complete this digital doc: Worksheet 13.1: Abiotic factors in an ecosystem (doc-12823)

13.3 How many are left?

13.3.1 Extinct or endangered?

Since European settlement hundreds of native Australian species have become extinct and many more are endangered. There have been some success stories however — some species have been saved from the brink of extinction. Monitoring the size of populations is an important step in conservation.

A species is extinct when all the members of that species have died out. The last Tasmanian tiger died in Hobart Zoo in 1936 and on that day Tasmanian tigers became extinct. Endangered species are at risk of becoming extinct. Their numbers have decreased dramatically over recent times, but well planned conservation efforts may save them from extinction.

Since Europeans first arrived in Australia numerous species of mammals, birds and other types of animals have become extinct and many more are critically endangered. A number of species of bilbies are endangered. These small marsupial mammals have large ears and look a bit like rabbits. Easter bilbies, a popular Easter chocolate treat, were first sold as a way to raise funds to support conservation efforts, although today most of the chocolate bilbies sold in stores are not associated with any fundraising programs.

Counting living things

To determine whether a species is endangered we need to estimate how many members of the species are left. We need to measure its abundance — how many there are in a particular area. Measuring the abundance of elephants in New South Wales would be easy. There are only a few elephants in New South Wales, at Taronga Zoo and Western Plains Zoo, and elephants are easy to see. If we had to measure the abundance of limpets on a rock platform we would have a much harder time. Two techniques that are sometimes used to estimate abundance are the quadrat method and the capture–recapture method. The quadrat method works best for species that do not move about much, such as trees or limpets. The capture–recapture method is more suited to species that move such as rabbits or fish.

HOW ABOUT THAT!

Dr Kathy Belov is an Australian scientist attempting to save a species from extinction.

Tasmanian devils are under threat. A deadly disease called devil facial tumour disease (DFTD) is spreading through the population. The disease is a type of cancer but unlike most cancers it is caused by a virus and is therefore contagious. It is passed on when devils bite each other. Within a few months of developing the first signs of the tumours the devils usually die as they find it difficult to eat.

Dr Kathy Belov's research has focused on why the Tasmanian devils are not able to fight off the disease. She has found that there is little genetic variation amongst the Tasmanian devils — they all have very similar genes and this is one of the reasons why the disease has spread rapidly amongst the devil population. Research is continuing in the hope that one day a cure or a vaccine will be developed.

Devil facial tumour disease is a deadly disease spreading through the Tasmanian devil population.

13.3.2 Life in a square

A quadrat is just a sampling area (often 1 m^2) in which the number of organisms in that area is counted and recorded. When organisms are counted in a number of quadrats, this is usually considered to be representative of the total area under investigation. The abundance of the organism in the total area can be estimated using the equation:

$$\text{estimated abundance} = \frac{\text{average number per quadrat} \times \text{total area}}{\text{area of quadrat}}$$

For example, some students counted the number of oysters in quadrats with an area of 0.25 m^2 and found the average number of oysters was 15. They then estimated the total number of oysters on the rock platform as follows:

$$\text{average of oysters per quadrat} = 15$$
$$\text{total area of rock platform} = 300\ \text{m}^2$$
$$\text{area of quadrat} = 0.25\ \text{m}^2$$
$$\text{estimated abundance} = \frac{15 \times 300}{0.25} = 18\,000$$

Students using quadrats to estimate the abundance of oysters.

INVESTIGATION 13.2

The quadrat method

AIM: To estimate the abundance of eucalypts in a forest

You will need:

Maps of environments A and B. These are available in your Resources tab. Each star on the maps represents a eucalyptus tree.

- Measure the length and width of each map and calculate the area of each using the following equation: area = length × width
- Make a quadrat by cutting a 3 cm × 3 cm square out of overhead transparency film. Calculate the area of the quadrat.
- Close your eyes and drop the quadrat anywhere on the map. Count how many eucalypts (crosses) are inside the quadrat. Repeat a further 4 times. Do this for both maps.

Discussion

1. Copy and complete the table below.

	Number of eucalypts	
Quadrat number	**Environment A**	**Environment B**
1		
2		
3		
4		
5		
Average		

2. Estimate the abundance of eucalypts in each environment using the equation below:

$$\text{Abundance} = \frac{\text{average number per quadrat} \times \text{total area}}{\text{area of quadrat}}$$

3. Count the actual number of eucalypts in each environment and compare your estimate to the actual answer.
4. What could you have done to make your estimate more reliable?

Counting moving animals can be particularly tricky. For these, the capture–recapture method is used. Some animals are captured and tagged, then released back into the environment. At a later stage the researchers return to the field and capture more animals. By working out what proportion of the recaptured animals are tagged, they can estimate the total number of organisms using the formula below:

$$\text{Total number} = \frac{\text{number of animals tagged on first visit} \times 100}{\text{average percentage of tagged animals per recapture}}$$

Example:
In order to estimate the number of koalas in a forest, Mrs Jones captured 50 koalas and tagged them. After tagging, the koalas were released. She visited the same area a further 5 times in the same year; each time she captured koalas and made a note of how many were tagged. Her results are shown below.

Recapture	Total number of koalas captured	Number of tagged koalas captured	% of koalas tagged
1	30	7	23
2	27	8	30
3	53	12	23
4	44	16	36
5	19	5	26

$$\text{Average percentage of tagged koalas per recapture} = 28\%$$

$$\text{Total number of koalas} = \frac{50 \times 100}{28} = 179$$

INVESTIGATION 13.3

The capture–recapture method

AIM: To model a method of estimating populations

Note: In this experiment beads will be used to represent fish and a large beaker will represent the pond in which they live.

You will need:

a large beaker
red and yellow beads (you can use other colours if needed)

- In your notebook, draw a table similar to the one shown below with enough room for 10 trials and the average.
- Place about 200 red beads in the large beaker (you do not need to count them exactly at this stage). These are the goldfish living in the pond.
- ‘Catch’ 25 of the goldfish and ‘tag’ them (replace 25 of the red beads with yellow beads).
- Mix the beads thoroughly.
- One student should close her eyes and randomly select 20 beads from the beaker. These are the recaptured goldfish. Count how many ‘fish’ are tagged (yellow beads) and untagged (red beads), and enter the numbers in the results table.
- Return the beads to the beaker and mix thoroughly. Repeat the above step a further 9 times.
- Calculate the average number of tagged and untagged fish per capture.
- Calculate the total number of fish using the equation shown in this subtopic.

Trial	Number of untagged fish (red beads)	Number of tagged fish (yellow beads)
1		
2		
⋮		
9		
10		
Average		

Discussion

1. Count how many beads were actually in the beaker and compare the actual number to the number you calculated using the capture–recapture method.
2. List any source of errors in this experiment.
3. Explain why this method can only be used for animals that move around. Why can’t it be used to estimate the number of trees in a forest, for example?

13.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. **Distinguish** between an extinct and an endangered species.
2. **Outline** why facial tumour disease eventually results in death in the Tasmanian devils.
3. **Identify** the procedure used to measure:
   (a) the abundance of species that do not move significantly during the counting process.
   (b) the abundance of species that move around.
4. Write the equation used in the quadrat method.

Using data

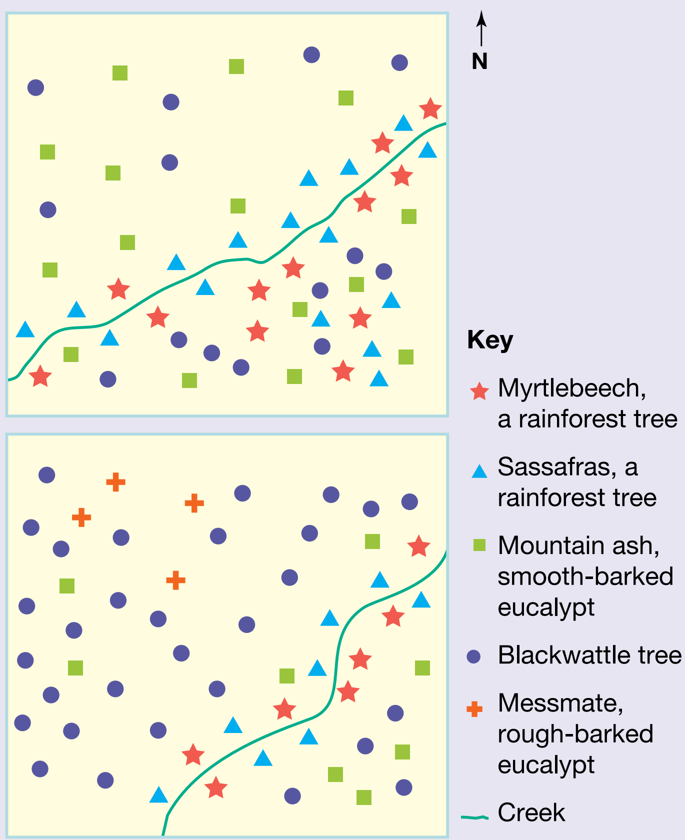
5. A biologist sets up ten quadrats, each with an area of one square metre, for sampling a population of clovers. The population counts for ten quadrats are:
   123, 134, 32, 156, 171, 153, 129, 142, 28 and 160.
   (a) What is the average population of clovers per square metre?
   (b) Suggest two possible reasons for the unusually low counts in two of the quadrats.
   (c) **Explain** why a number of quadrats were used to estimate the total number of clovers.

6. Sharie wanted to estimate the number of cockroaches living in her uncle's restaurant. One evening after the restaurant was closed she caught 15 cockroaches. She put a dab of coloured paint on their back, and then released them. Each night for the following week she captured cockroaches at the restaurant and made a note of how many had a coloured dot on their back. Her results are shown below:

Day	Total number of cockroaches captured	Number of tagged cockroaches	% of tagged cockroaches
Monday	11	5	
Tuesday	8	3	
Wednesday	19	6	
Thursday	15	7	
Friday	18	7	

(a) **Calculate** the values for the third column in the table.
(b) **Calculate** the total number of cockroaches in the restaurant.
(c) List some sources of error in this estimate.

7. The location of five different types of trees in the two quadrats at right is indicated by the five different symbols.
(a) Count and record the number of the different species in each quadrat.
(b) **Identify** which quadrat provides a greater variety of habitat types for wildlife. **Explain** your answer.
(c) **Propose** why the rainforest species in both quadrats are located most densely near the creek.



Investigate

The investigations below should be carried out on a field trip to a natural environment.

8. Use the quadrat method to estimate the abundance of a species in a natural environment. Depending on the location of your school you could estimate the abundance of a type of plant in an area of shrubland or park near your school, or even estimate the abundance of clovers in an area of the playground.
9. Use the **Quadrat method** interactivity in the Resources tab for a virtual experience of this method of sampling.
10. Use the **Capture–recapture method** interactivity in the Resources tab for a virtual experience of this method of sampling.

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Complete this digital doc: Worksheet 13.2: Estimating the size of a population (doc-12824)

13.4 Ecosystems are solar powered

13.4.1 Photosynthesis

All living things require a source of energy. Animals get their energy from the food they eat. Plants do not ingest food. They harvest energy from the sun to produce sugars. These sugars, in turn, can either be converted to other compounds or used in respiration to release energy.

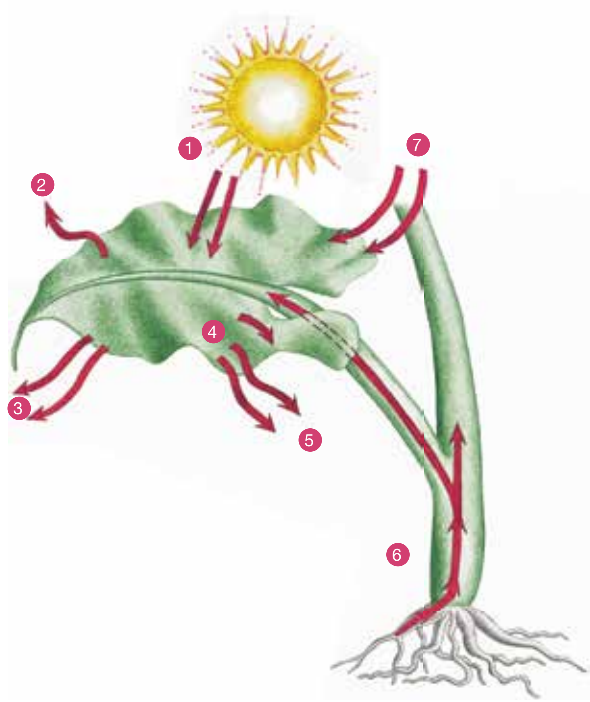
Photosynthesis is a process carried out by plants, algae and some unicellular organisms that contain the pigment chlorophyll. In this process the sun's light energy is used to convert carbon dioxide and water into glucose and oxygen. This is shown in the equation below:

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{glucose} + \text{oxygen.}$$

That is:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6O_2.$$

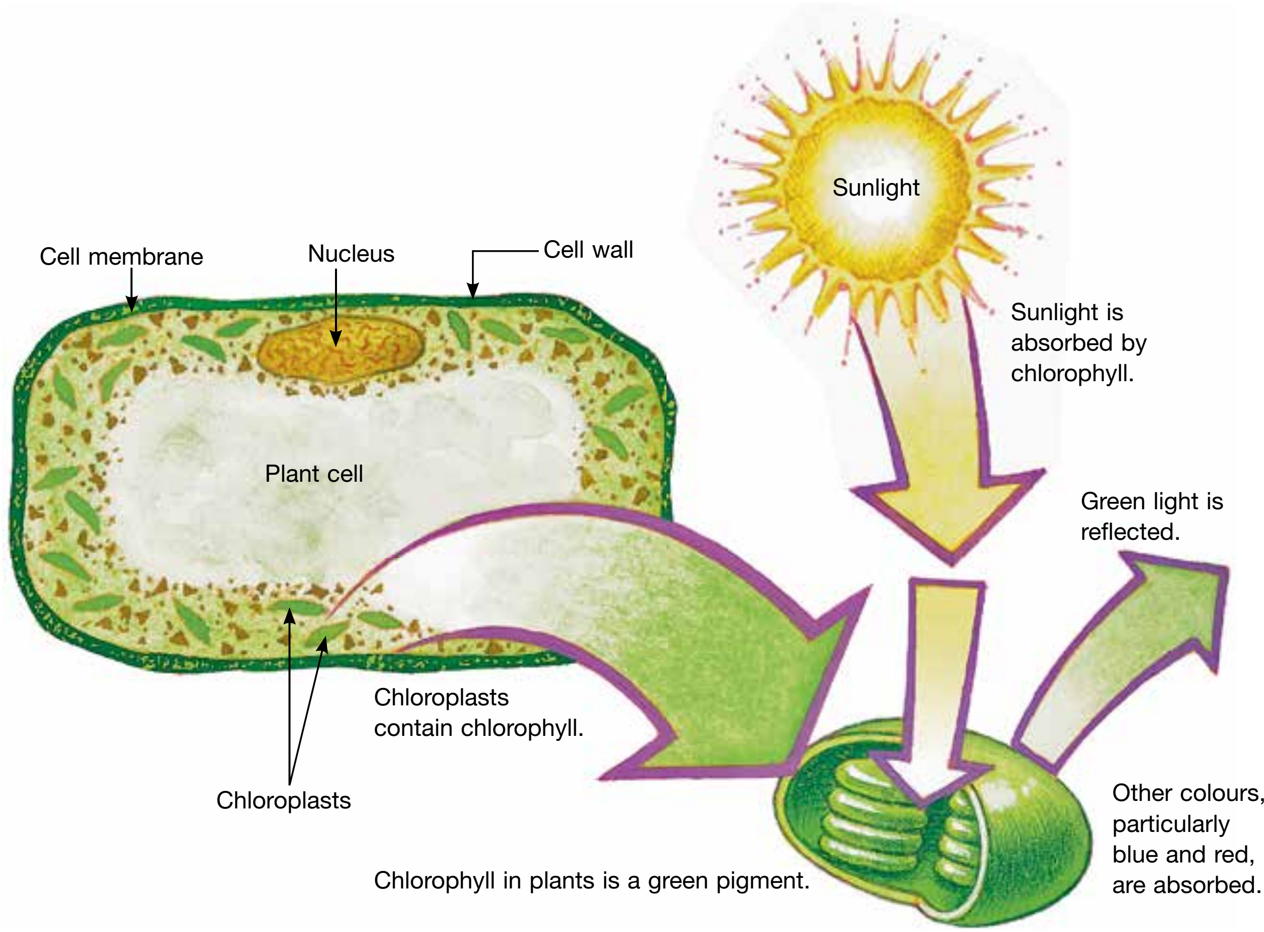
Glucose is a high energy compound. Some of the glucose produced in photosynthesis is used for respiration, a process that releases energy (see section 13.4.4). The glucose that is not used in photosynthesis is converted into other compounds including starch, cellulose and sugars such as fructose, the sugar found in fruit. Converting glucose to starch is one way that plants can store energy for later use, in the same way that our bodies store energy as fat when we eat more food than our bodies need. At night, when photosynthesis no longer occurs, starch can be broken down into glucose so that respiration can continue in the absence of light.



1 Light energy from the sun is trapped by chlorophyll in leaves.
2 Some water is lost.
3 **Oxygen** exits the leaves through the stomata.
4 Glucose is stored as **molecules** of starch. Glucose is the instant energy used to make materials for the body of the plant
5 Some energy is lost as heat by the plant during photosynthesis.
6 Water is carried up from the soil in the stem by tubes of xylem tissue.
7 Carbon dioxide enters the leaf through the stomata (tiny holes) on the underside of the leaf.

13.4.2 Chlorophyll is needed for photosynthesis

Photosynthesis occurs in the chloroplasts of plant cells. These appear as tiny green dots inside cells when viewed under a microscope. The chloroplasts are green because they contain the pigment chlorophyll which can absorb sunlight. Some of the unicellular organisms that carry out photosynthesis, including cyanobacteria (blue-green algae), do not have chloroplasts but they still contain chlorophyll.



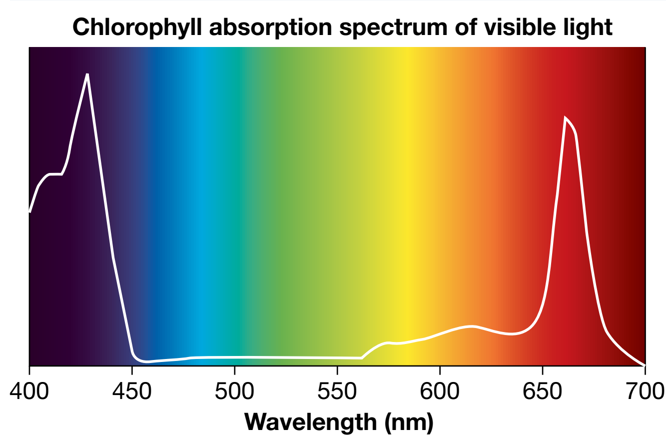
13.4.3 Why are plants green?

Chorophyll is green because it reflects green light and absorbs other colours of light, particularly red and blue light. Some plants are not green though. That's because they contain other pigments that mask the green colour of chlorophyll.

Algae that live deep in the ocean are often red or brown in colour. This has to do with the fact that red light does not travel very deep into the ocean. These algae contain pigments that can absorb the colours of light that reach deeper into the ocean.

The energy stored in the glucose made by plants can be released in a chemical reaction called **cellular respiration**. This chemical reaction takes place in the **mitochondria** of cells in all plants. It also occurs in the mitochondria of cells in animals, fungi and other organisms.

Chlorophyll absorbs mainly light in the blue and red range of the spectrum.



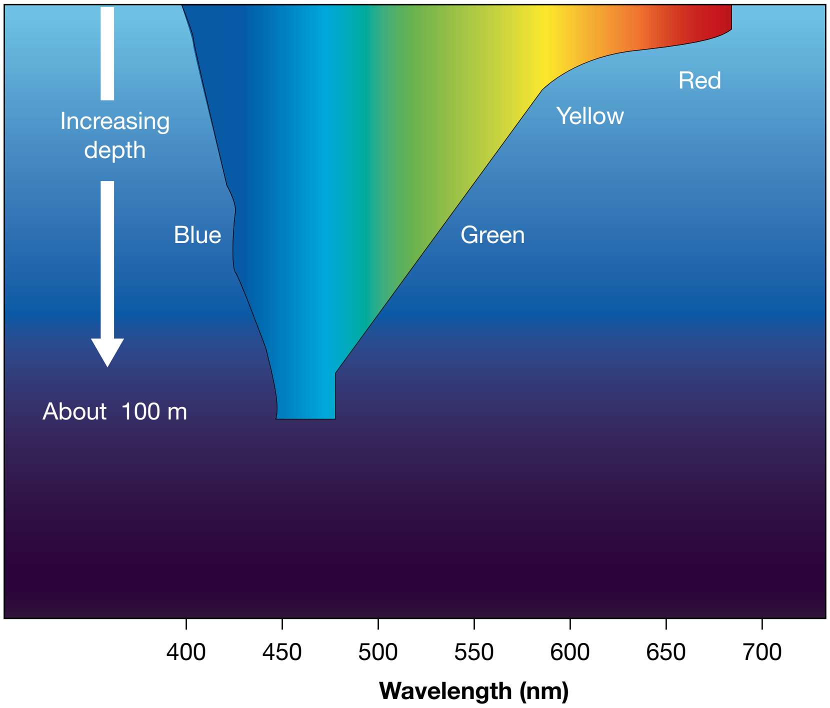
There are different types of respiration. When there is plenty of oxygen around, aerobic respiration usually occurs. In this reaction, glucose reacts with oxygen to produce carbon dioxide and water, and chemical energy is released. This can be written as:

glucose + oxygen → carbon dioxide + water + energy

or

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + \text{chemical energy.}$$

Red light does not travel very deeply into the ocean.



INVESTIGATION 13.4

Detecting glucose and starch in plants

AIM: To detect starch and glucose in plant leaves

You will need:

iodine solution in a dropper bottle
1% starch solution
white tile or blotting paper
leaves from seedlings or plants of one type (geranium, hydrangea, lettuce, spinach or silverbeet cuttings are good)
glucose indicator strip with colour chart
1% glucose solution in a dropper bottle
mortar and pestle
sand
small beakers or petri dishes for testing different substances

- Construct a table like the one below for recording your observations.

	Iodine test		Glucose test	
Item tested	Colour	Starch present?	Colour	Concentration of glucose

Testing leaves for starch

- To observe the effect of iodine solution on starch, place a few drops of starch solution on a piece of blotting paper or a white tile. Add a few drops of iodine.
- Soften two or three leaves by dipping them with tongs into hot water for 10 seconds.
- Repeat the test with the softened leaves. Keep one leaf aside that is not tested with iodine to compare it with the leaves that you test.

Testing leaves for glucose

- Record the colour observed and the presence of starch in your table.
- To observe the effect of glucose on the glucose indicator strip, place a drop of glucose solution on the end of the strip on a white tile.
- Use the chart of colours to determine the concentration of the glucose.
- Using the mortar and pestle, grind some fresh leaves with a little water and a sprinkle of sand.
- Allow a strip of glucose indicator paper to soak up the liquid.
- Record the colour and glucose concentration in your table.

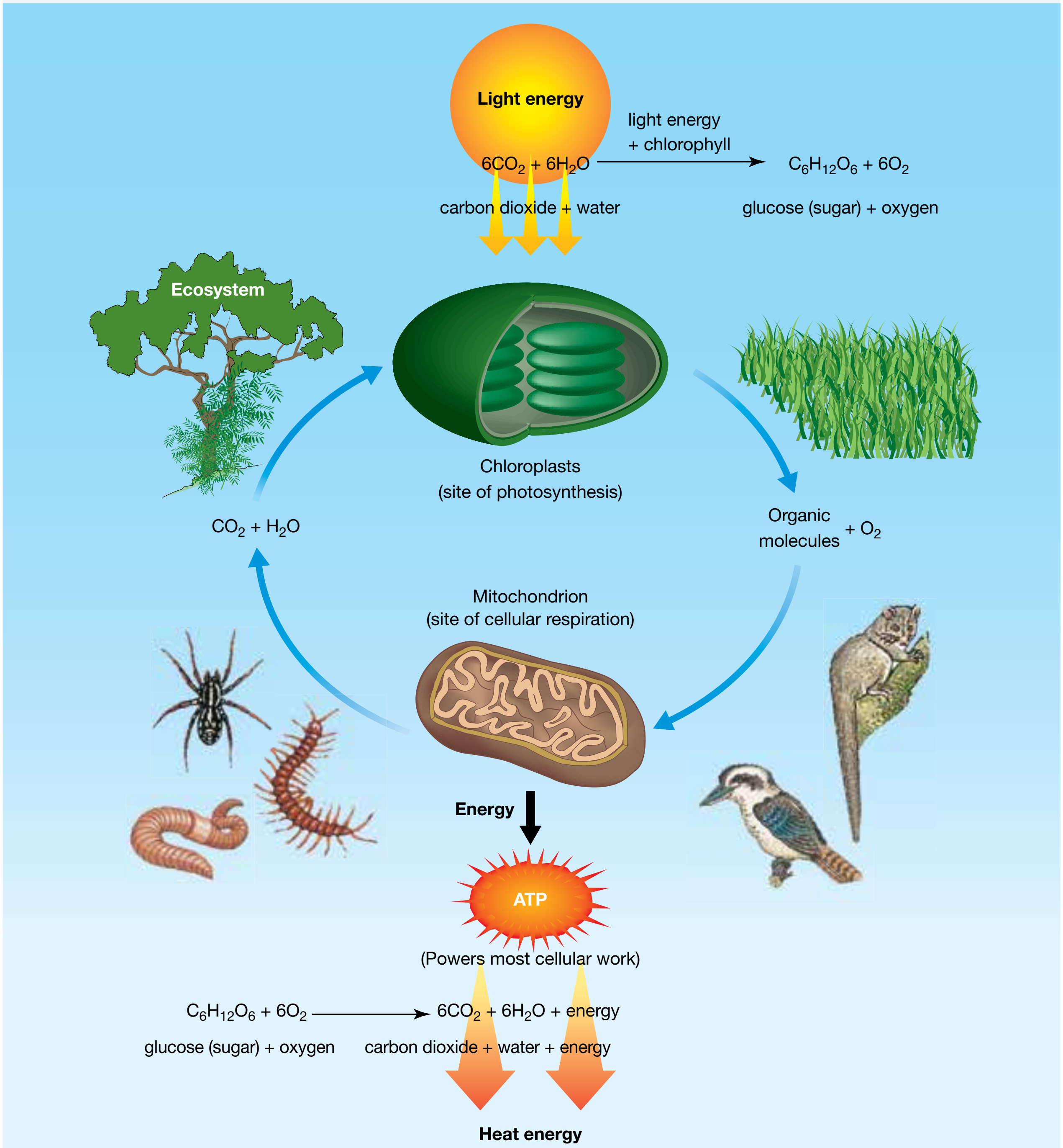
Discuss and explain

1. Describe the effect of the iodine on the starch solution.
2. Describe the effect of the glucose solution on the indicator strip.
3. What do your results suggest about the way energy is stored in leaves?
4. Why was sand added to the mixture in the mortar?
5. The sand does not affect the result on the indicator strip. How could you show this?
6. Identify the strengths of this investigation.
7. Suggest improvements to the design of this investigation.
8. Suggest a hypothesis that could be investigated using similar equipment. (You may use internet research to identify relevant problems to investigate.)
9. Design an experiment to test your hypothesis. Include an explanation for your choice and treatment of variables.
10. Share and discuss your suggested hypothesis and experimental design with others and make any relevant refinements to improve it.

The chemical energy released during cellular respiration is used to make a substance called ATP. ATP is an abbreviation for **adenosine triphosphate**. Molecules of ATP store the chemical energy needed by cells to power energy conversions. They act like rechargeable batteries. The energy stored in ATP molecules is the only form of stored chemical energy that animals can use to keep their bodies working and active.

Not all of the energy released during cellular respiration is stored in ATP. A large percentage of it is released as heat.

Photosynthesis and respiration link the journey of energy through the ecosystem.



Photosynthesis and respiration make up part of the path of energy through ecosystems. Plants convert sunlight to build glucose molecules during photosynthesis. When glucose gets broken down in animals and plants during respiration, stored energy is released in cells. Whenever energy is converted through photosynthesis or respiration, some energy is released to the environment as heat.

HOW ABOUT THAT!

Life in the dark

An angler fish, one of the strange creatures found in some deep ocean ecosystems

All *ecosystems* must have producers. Scientists were baffled for many years by the existence of life on the deep ocean floor where no photosynthetic plants or phytoplankton could live. In 1980, it was discovered that light-deprived ocean floor ecosystems had a different kind of producer. A type of 'primitive' bacterium called sulfur bacteria is actually the producer in this totally dark ecosystem. Sulfur bacteria are able to exist in such a dark world (often more than two kilometres below the surface) because they use chemosynthesis rather than photosynthesis to make their food. Giant clams, vent crabs, pompeii worms, jellyfish and tubeworms all depend on sulfur bacteria for food energy.

Sulfur bacteria use chemical energy from reactions involving oxygen and hydrogen sulfide (H_2S) to make food. Interestingly, H_2S is toxic to most plants and animals. It is commonly known as 'rotten-egg gas'.

The bacteria obtain the substances they need from water that is circulated in and out of cracks (hydrothermal vents) in the ocean floor. Sulfur bacteria use toxic chemicals to make their own food in total darkness, and in very hot water and under high water pressure. Bacteria such as these that can withstand very high pressures and temperatures have potential uses in many industries. Perhaps these ancient organisms could be used as food sources for other consumers — maybe even in an ecosystem on another planet!

13.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Write a word equation and a symbol equation for photosynthesis.
2. **Identify** the gas removed from the atmosphere by photosynthesising organisms.
3. Apart from plants, which other organisms carry out photosynthesis?
4. **Outline** how glucose is stored in leaves.
5. What is chlorophyll? Where is it found in plants?
6. Which colours of light penetrate deepest into the ocean?
7. In your own words, **describe** the respiration process. Include an equation in your answer.
8. **Describe** what happens to the chemical energy released during cellular respiration.

Think

9. **Predict** the impact of the following on the rate of photosynthesis:
   (a) an increase in light intensity (brighter light)
   (b) an increase in carbon dioxide concentration in the atmosphere.

10. Where in the world would you expect plants to grow fastest? **Justify** your answer.
11. **Explain** why algae that live deep in the ocean are often red or brown in colour.
12. Would you expect plants to grow fastest under blue, red or green coloured light? **Explain** your answer.
13. **Compare** photosynthetic and chemosynthetic organisms.

Investigate

14. Design an experiment to test whether the colour of light plants are exposed to affects the rate at which they grow.

13.5 The flow of energy in ecosystems

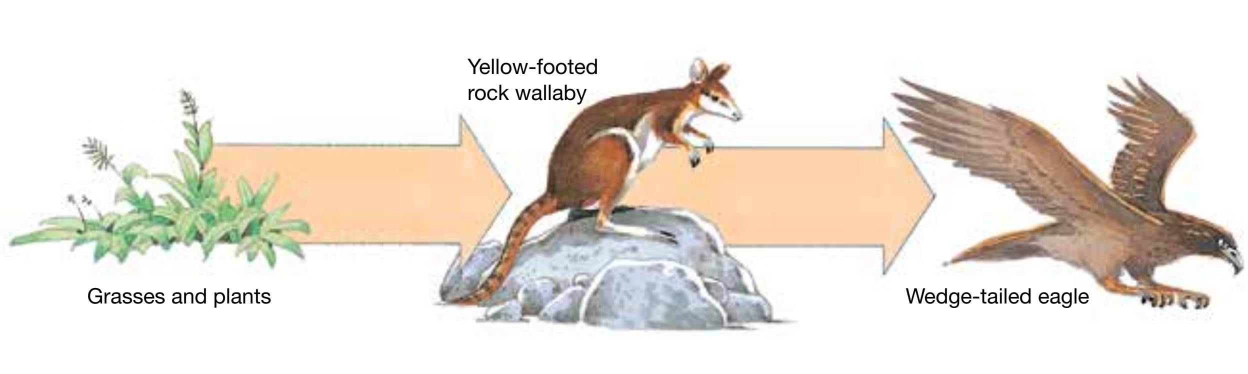
13.5.1 Food chains and food webs

Food chains and food webs can be used to track the flow of energy in ecosystems. The arrows show the direction in which energy is transferred.

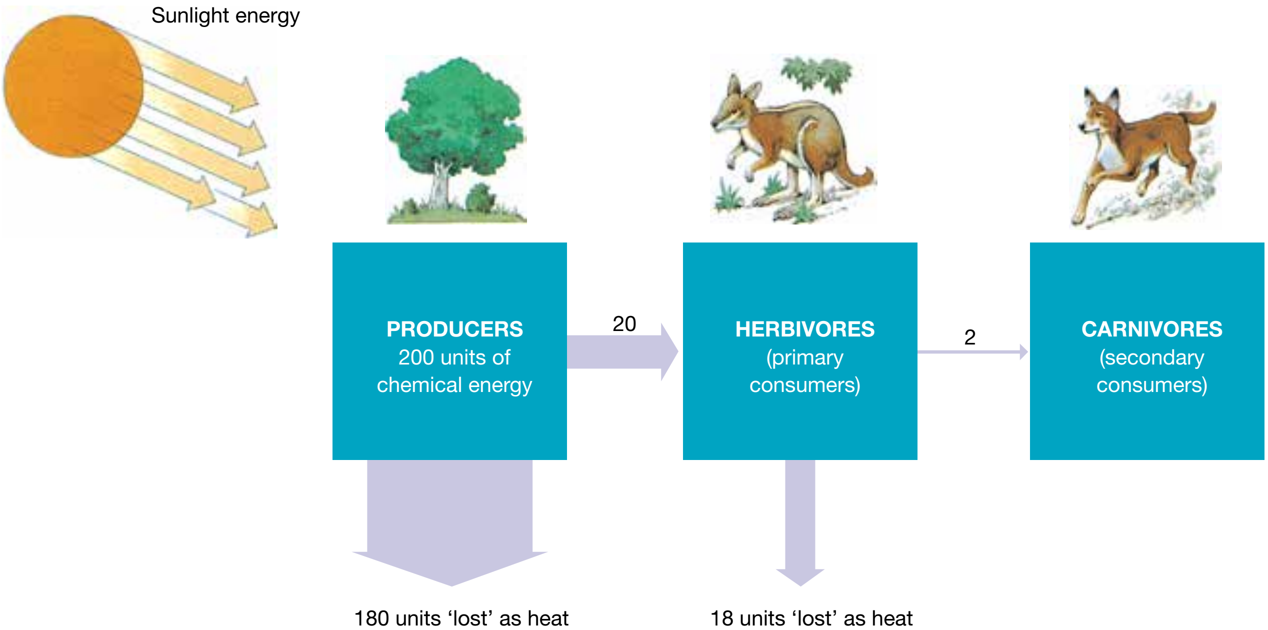
A food chain is a simple diagram that starts with a producer — in most instances an organism that carries out photosynthesis. When producers are eaten by first-order consumers, some of the energy locked up in the producers is transferred to the next stage of the food chain. Some of this energy, in turn, is transferred to the following stage. Food chains vary in length. Only a small portion of the energy from each organism in the food chain is transferred to the next level.

A number of interconnecting food chains can be organised into a food web. When constructing a food web, the producers are usually placed at the bottom of the diagram with the arrows pointing upwards. Setting out the food web in this manner makes it easier to identify the trophic (feeding) levels. The plants and other producers make up the first trophic level. The first-order consumers are the herbivores and they make up the second trophic level. The third trophic level consists of the second-order consumers — carnivores that feed off herbivores. Most food webs have 3 or 4 trophic levels.

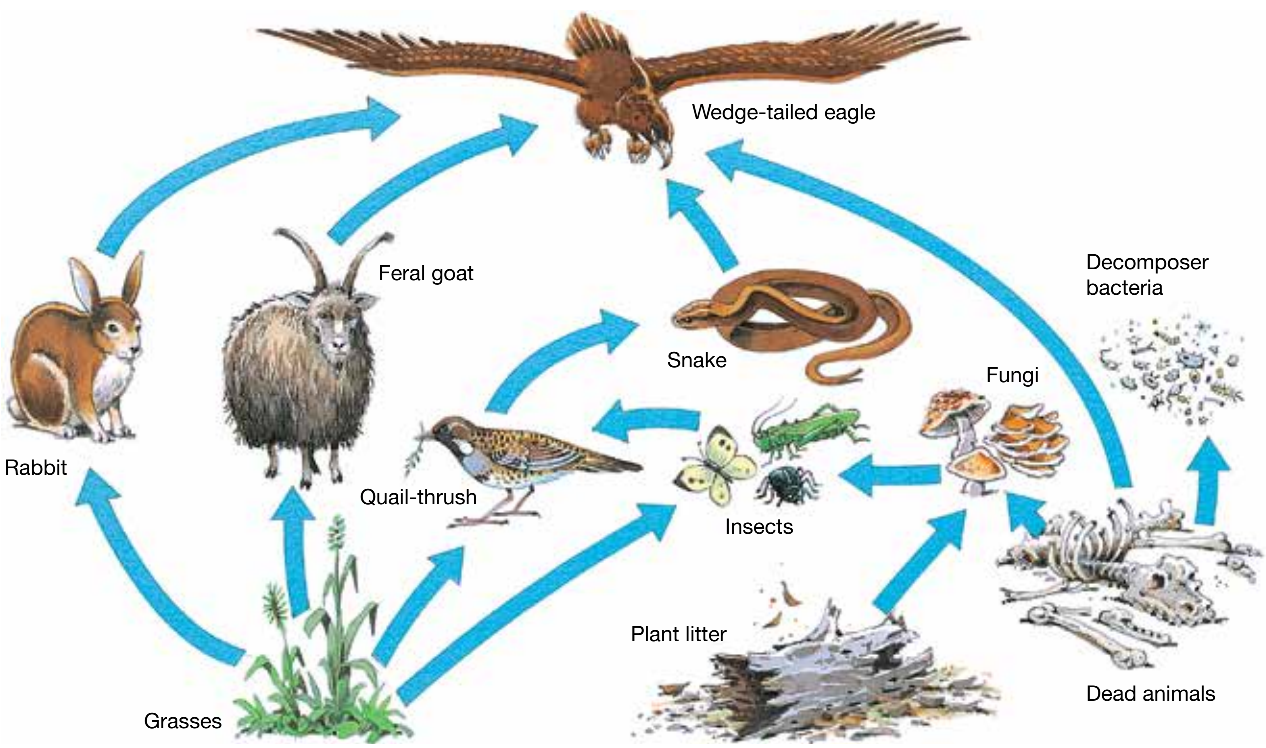
A food chain



Energy flow in an ecosystem. The values are averages. Is the amount of energy that enters a trophic (feeding) level equal to the amount that flows to the next level?

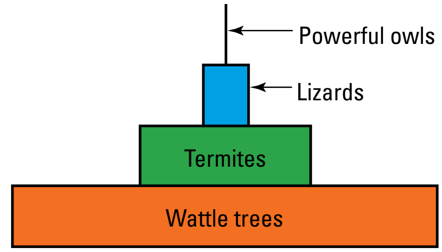


A food web showing the flow of chemical energy through the different kinds of organism in an ecosystem



Not all the energy is transferred from one trophic level to the next. Some of the energy is transformed into other forms of energy, including heat. For this reason a large mass of producers is needed to support a small number of top-level consumers. This can be shown using a biomass pyramid. Biomass refers to the dry mass of the organisms that make up each trophic level.

A large mass of wattle trees is needed to support just a few owls with a small biomass.



13.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What do the arrows in food webs indicate?
2. Match each item in the left-hand column with an item in the right-hand column.

(a) Producer	(i) Animal that eats only plant matter.
(b) Consumer	(ii) Diagram that represents the trophic relationships in an ecosystem.
(c) Herbivore	(iii) Animal that eats only other animals.
(d) Carnivore	(iv) Organism that does not need to ingest food.
(e) Food web	(v) Organism that needs to ingest food.

3. **Identify** the type of organism that occupies the lowest trophic level in a food web.

Think

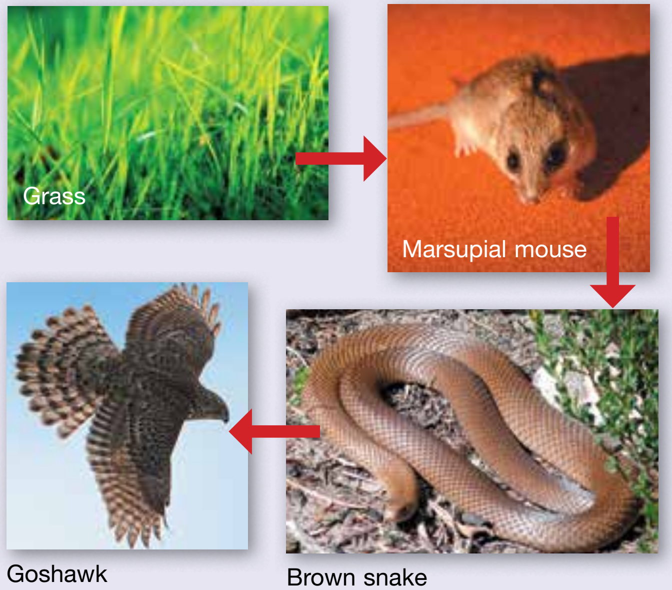
4. Only a small portion of the energy stored in the organisms of a trophic level ends up being stored in the organisms that make up the next trophic level. **Outline** what happens to the remainder of the energy.
5. **Explain** why most food chains have only 3 or 4 levels.
6. Some people choose to be vegetarian out of concern for the environment. **Explain** why eating large quantities of meat rather than plant matter is not as environmentally friendly as a plant-based diet.

Skill builder

7. Study the food chain given on page 520.
   (a) In times of drought little grass grows and many plants die. **Outline** the impact on the population of yellow-footed wallabies and wedge-tailed eagles.
   (b) Imagine that a disease wiped out most of the population of wedge-tailed eagles. Sketch a line graph to show what might happen to the wallaby population over time. What would limit the growth of the population?
8. Study the food web given on the previous page.
   (a) **Identify** the longest food chain in the food web.
   (b) **Identify** the following:
      (i) first-order consumers
      (ii) top-level consumer
      (iii) a producer.
   (c) The myxomatosis virus is deadly to many rabbits. **Describe** the impact of the virus spreading through the rabbit population in the ecosystem represented in the food web.
9. (a) Use the information at right to **construct** a food web for a coastal ecosystem
   (b) **Predict** the impact of over-fishing of the large fish on the abundance of sharks, the small fish and crabs.

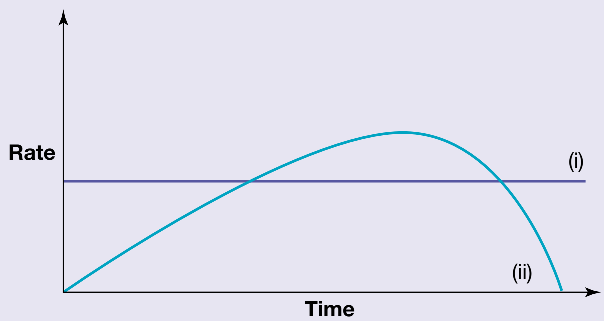
Organism	What it feeds on
Seabird	Crab, mussel, small fish
Human	Crab, mussel, small fish, large fish
Shark	Large fish
Large fish	Small fish
Small fish	Phytoplankton, algae (both producers)
Worms	Phytoplankton, mussel

10. **Construct** an energy pyramid for the following food chain.



11. **Analyse** the graph at right to answer the following questions.
    (a) Which line of the graph represents the rate of photosynthesis?
    (b) When would the rate of respiration be greater than the rate of photosynthesis?

This graph shows the rates of photosynthesis and respiration for a plant over a 24-hour period.



Investigate

12. What is phytoplankton and why is it so important to ocean ecosystems?
13. Are carnivorous plants producers, consumers or both? You can find out the answers to this by using the **Carnivorous plants** weblink in the Resources tab.
14. **Investigate** and report on the 'hottest creatures on Earth' that live in deep-sea hydrothermal vents. You will find some of these creatures by using the **Deep sea** weblinks in the Resources tab. In your report, **describe** the creatures and how they survive.

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- **Explore more with this weblink:** Carnivorous plants
- **Explore more with these weblinks:** Deep sea
- **Complete this digital doc:** Worksheet 13.3: Food webs (doc-12825)

13.6 Cycling of materials in ecosystems

13.6.1 Where does the matter that makes up organisms come from?

While energy flows through ecosystems, matter is recycled. The atoms that make up your body already existed when dinosaurs roamed the Earth, and when you die they will be returned to the atmosphere and the soil to be taken up by other organisms.

Plants take up some elements from the soil; for example, they take in nitrogen, mainly in the form of nitrate or ammonium ions and phosphorus as phosphate ions through their roots. The elements that are present in the greatest amounts in plants are carbon, oxygen and hydrogen. As plants carry out photosynthesis, the atoms that make up carbon dioxide (from the air) and water (from the soil) are incorporated into the matter that makes up the plant, so plants are made up mostly of atoms found in the air and water, and mineral ions they take up from the soil.

The matter that makes up animals comes from the food they eat. Some of the matter that makes up the food they eat is used to make chemical substances found in the animal's body. Some of the matter is broken down and used as a source of energy for metabolic processes, and some matter is excreted or egested from the body. Urine is excreted from the body and faeces are egested.

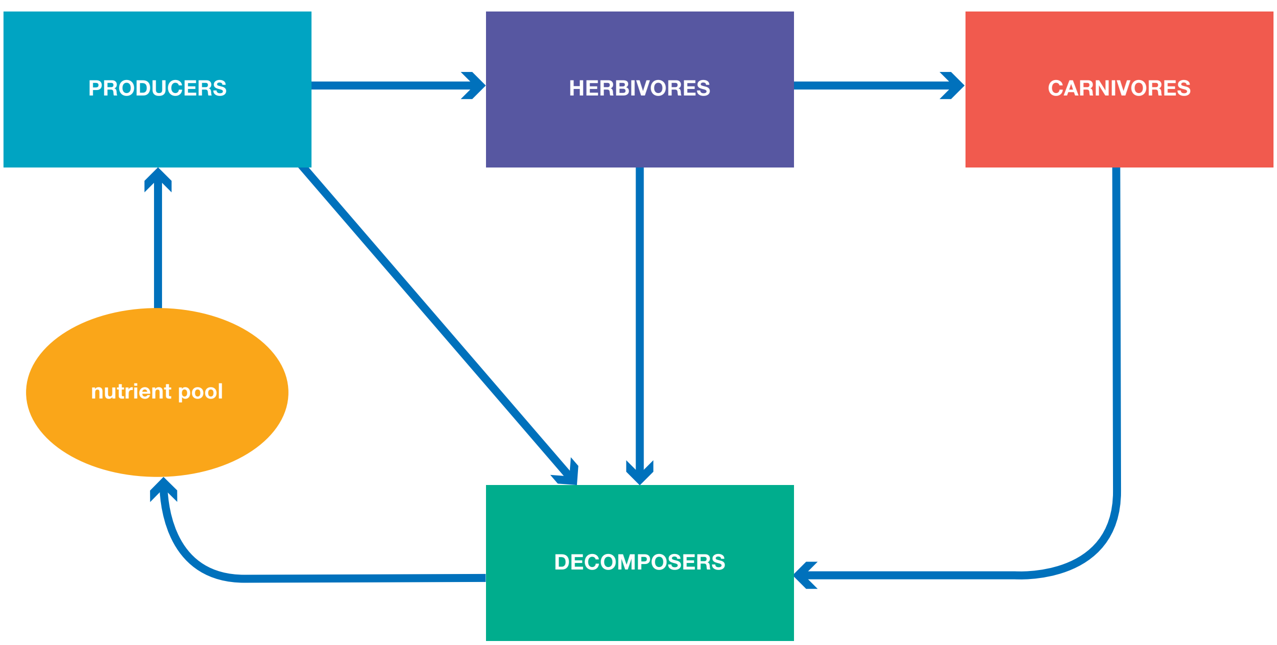
13.6.2 Where does the matter go when organisms die?

Whether organisms are burned, eaten by scavengers or left to decay, the matter that makes them up is recycled. When trees are burned in a bushfire, most of the matter ends up in the atmosphere in the form of various gases and smoke. Only a small amount of ash is left behind. Ash is rich in calcium, phosphorus and iron. Over time, the ash combines with the soil and the useful substances it contains are taken up by plants.

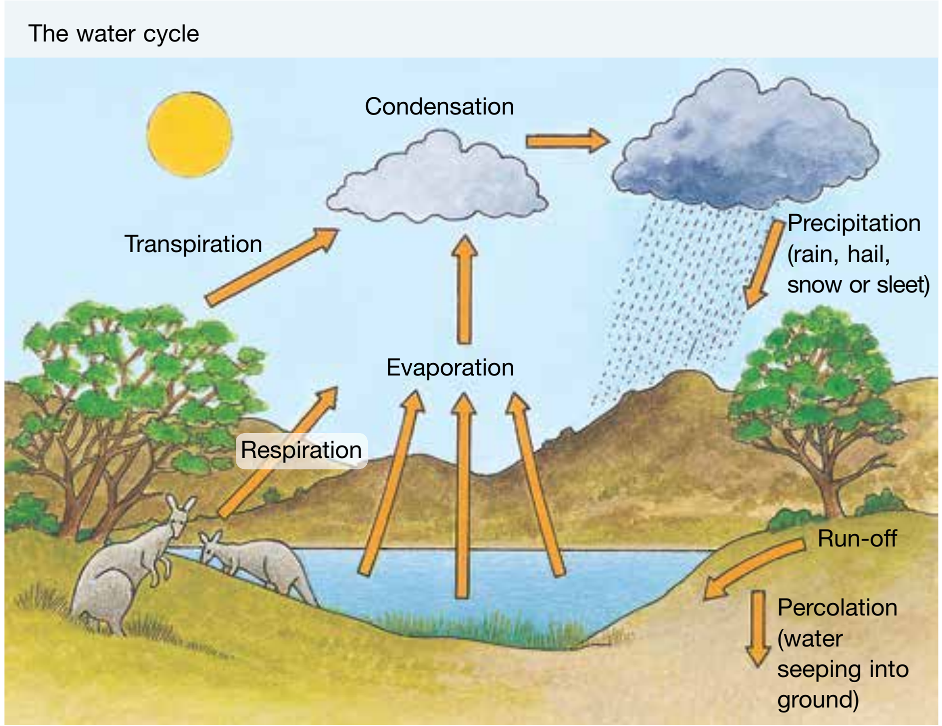
Scavengers are animals that feed on dead organisms. Many insects, some birds, fish and crustaceans are scavengers. They feed off the dead organisms and take in the chemical compounds that are needed.

Decomposers include many types of bacteria and fungi as well as worms. They break down dead organisms and return the atoms in their bodies to the atmosphere or the soil.

Matter cycles through ecosystems.

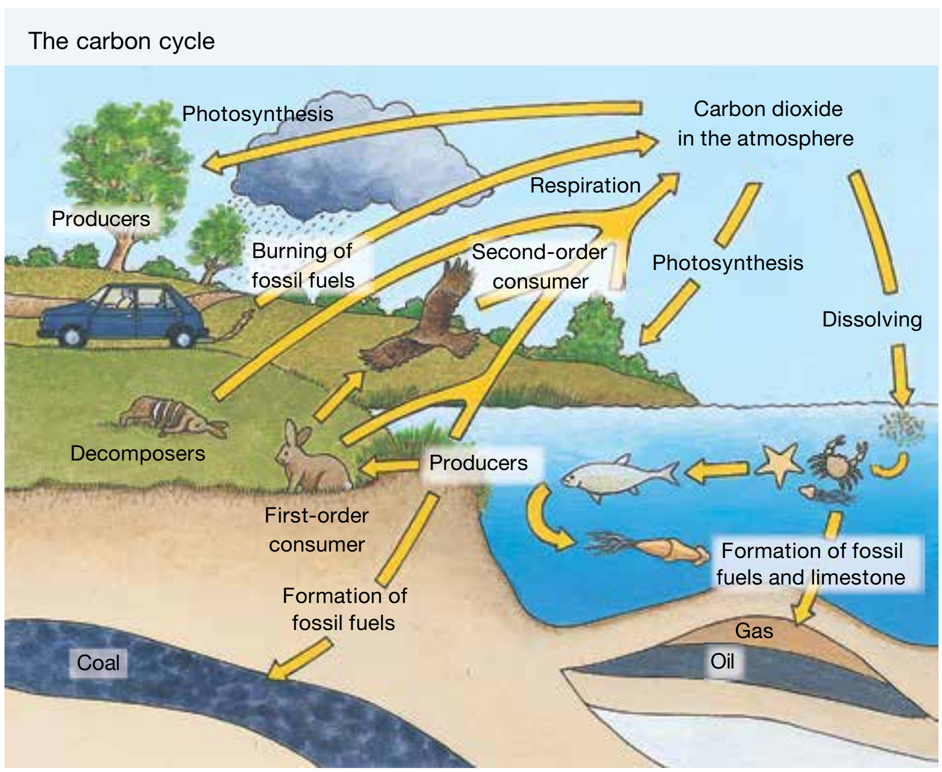


13.6.3 The water cycle



Water, warmed by energy from the sun, evaporates from lakes, rivers, oceans and the soil surface to form water vapour in the atmosphere. When the water vapour condenses into large droplets, rain falls on both land and water bodies. When rain soaks into the soil it becomes soil water. This water is found in between the grains of soil and is taken up by plants. As it passes through plants, some of the water molecules are involved in the process of photosynthesis. The rest of the water molecules pass through the plant body and out through the stomata, to become water vapour in the atmosphere again. This process is called **transpiration**. Transpiration occurs because the sun causes water to evaporate from the leaves of plants. If it did not, water would not move up the inside of the plant.

13.6.4 The carbon cycle



Carbon atoms exist in the atmosphere in carbon dioxide gas. Carbon dioxide is absorbed by plants, where it is combined with water and turned into glucose molecules. Oxygen is also produced. After more chemical reactions, the carbon is stored in complex molecules in the plant body. When an organism consumes a plant, it ingests the plant's carbon atoms, which then become part of the organism's body. The carbon is found in the compounds that make up carbohydrates, fats and proteins. When organisms respire, the carbon atoms combine with oxygen atoms to form carbon dioxide, which is then released to the atmosphere. If plants or the fossil fuels that form from plants are burnt, carbon atoms again combine with oxygen atoms to form carbon dioxide, which is released to the atmosphere. Carbon dioxide also dissolves in the sea. Here it is absorbed by sea plants and other sea organisms that photosynthesise. These producers are consumed by fish and other sea creatures, which are, in their turn, consumed by other organisms. Some of the carbon becomes part of coral reefs and shells, which, over millions of years, form limestone. Limestone is mined and, when heated in factories, releases carbon dioxide to the air, where it can again be absorbed by plants.

13.6.5 The nitrogen cycle

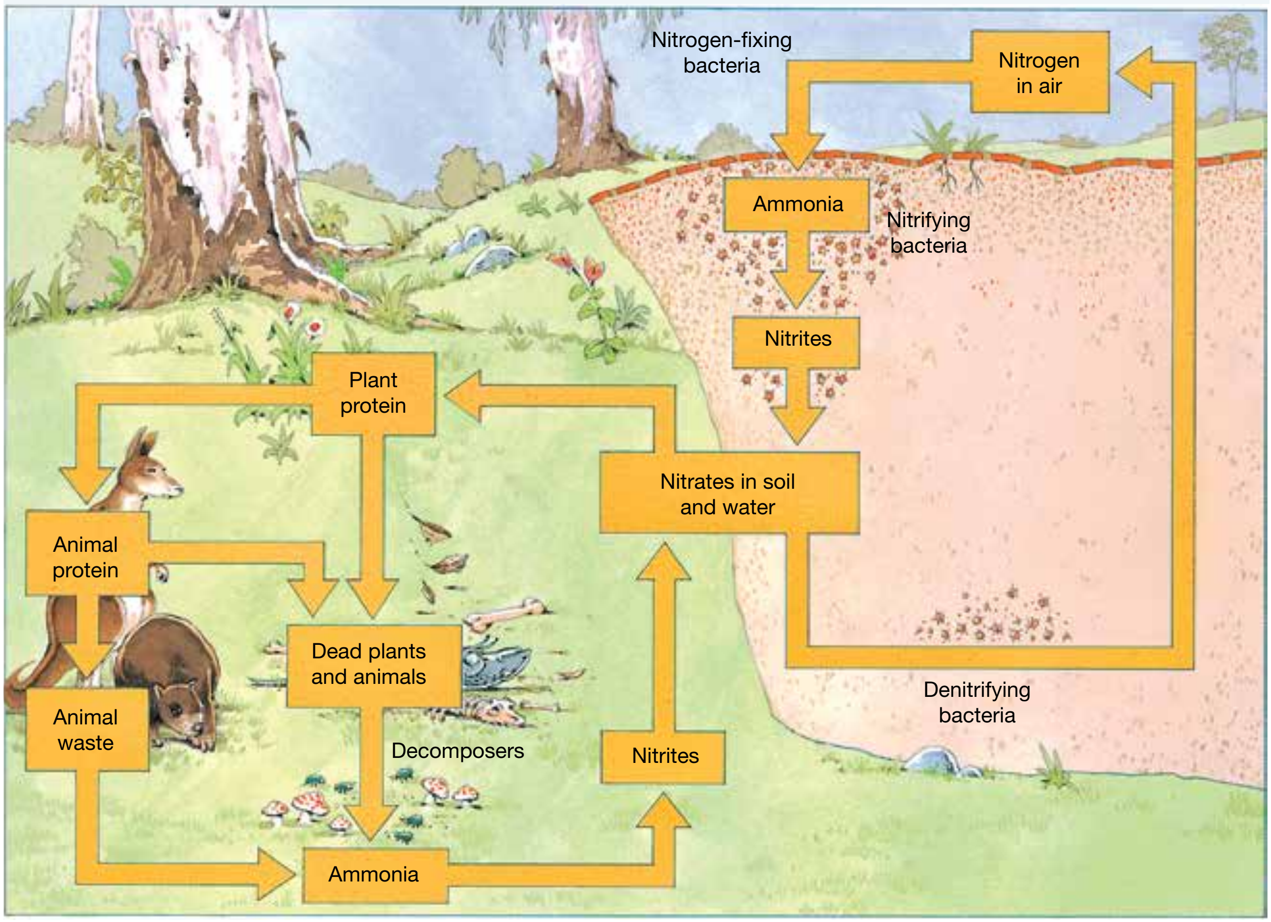
Nitrogen is an element that is essential to build proteins. Approximately 78% of the air is made up of clear, colourless and unreactive nitrogen gas. Although plants and animals need nitrogen atoms for the production of protein, they are not able to absorb the nitrogen from the air to enable this to happen.

Before plants can take up nitrogen, it needs to be converted into a form that can be taken up by the plant. This job is performed by nitrogen-fixing bacteria. These bacteria are found in soil. Some plants, including legumes, have nodules on their roots where nitrogen-fixing bacteria live.

Another group of bacteria that play an important role in the nitrogen cycle are nitrifying bacteria. They are also found in the soil. They help to break down some of the nitrogen-containing compounds including the waste products from animals. The action of bacteria results in soil containing nitrogen compounds that plants can take up. The plants use the nitrogen they take up from the soil to make proteins and other nitrogen-containing compounds. When animals eat the plants, they take in the nitrogen compounds locked inside the plant.

There is also a group of bacteria that convert the nitrogen in soil into nitrogen gas, thus putting the nitrogen back into the atmosphere. Even thunderstorms can impact on the nitrogen cycle. Lightning can convert nitrogen gas in the atmosphere into nitrogen-containing compounds.

The nitrogen cycle

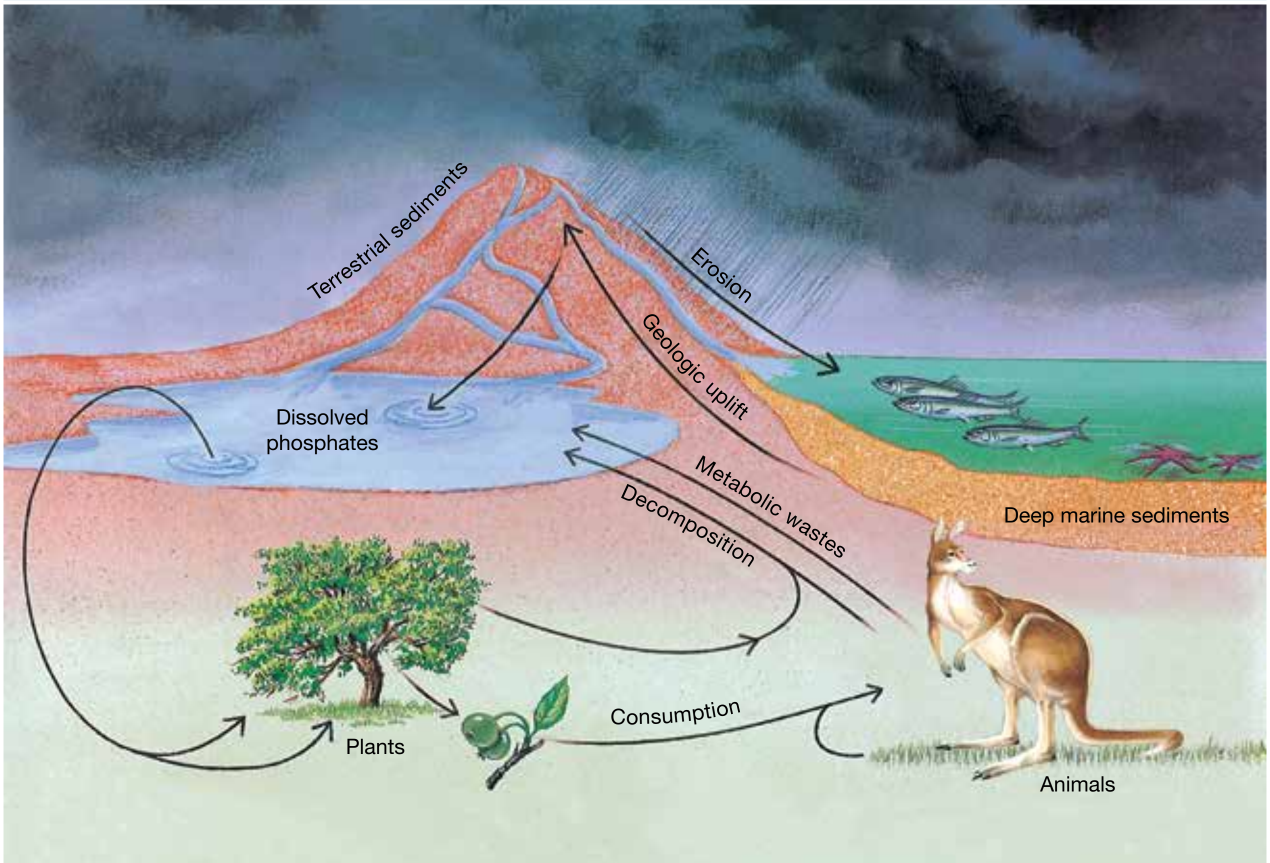


13.6.6 The phosphorus cycle

The phosphorus cycle is very slow and involves rocks containing phosphate compounds. As the rocks erode, the phosphate compounds are incorporated into soil and dissolve in streams, rivers, lakes and oceans. Plants take up the phosphate from the soil, so that when animals eat the plants they take in the phosphate compounds. After they die, the animals and plants decompose and the phosphates are returned to the soil.

The phosphate ions that end up in lakes and oceans react with substances in the water to form insoluble salts that become incorporated in the sediments that form at the bottom of lakes and oceans. These sediments eventually become sedimentary rock, which will in turn be eroded to repeat the whole cycle.

The phosphorus cycle



13.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the terms ‘scavenger’ and ‘decomposer’.
2. **Identify** the process that removes carbon dioxide from the air and converts it to glucose.
3. **Explain** why transpiration is necessary in plants.
4. **Identify** the organisms that are responsible for converting nitrogen from the air into a form plants can take up.
5. **Explain** why animals and plants need nitrogen.
6. **Identify** two sources of phosphates in soil.
7. How is the phosphorus cycle different from other nutrient cycles such as the carbon, nitrogen and water cycles?

Think

8. **Explain** the role played by plants in the carbon cycle.
9. Native Australian plants have adapted to low levels of phosphorus in soils. Their roots accommodate a fungus that releases phosphates. They also *recycle* phosphates inside their leaves. Why is it better to plant native plants in parks and gardens rather than plants from other countries?

Investigate

10. Use reference books or the internet to find the answers to the following questions.
    (a) **Identify** the main plant nutrients found in most fertilisers.
    (b) **Distinguish** between organic and non-organic fertilisers.
    (c) **Account** for the fact that plants that are native to Australia may not tolerate large amounts of certain fertilisers.

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Complete this digital doc: Worksheet 13.4: Cycling of materials (doc-12826)

13.7 Keeping track of species

13.7.1 Transects

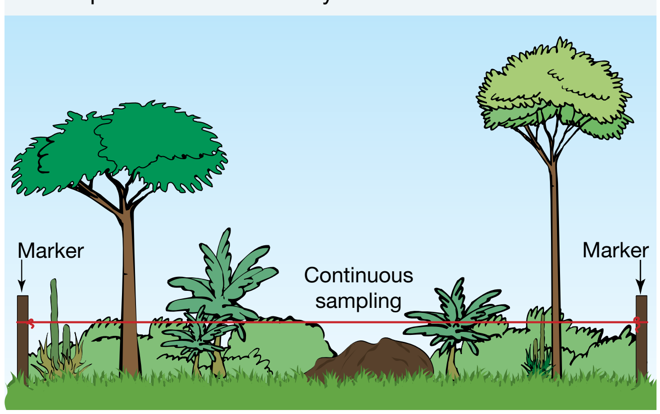
Having some knowledge of the distribution of a species — where the species is found — is critical to its conservation. It is also important to know how factors in the environment affect the population over time.

The distribution of a species is where it is found. This in turn can provide some clues about the factors that determine whether a particular species can survive in an area. One way of collecting data about the distribution of a species in an ecosystem is to use a transect. This involves recording all the organisms found in a narrow strip of an ecosystem. To draw a transect of a rock platform you would use the following steps.

- Stretch a rope from the water's edge to the part of the rock platform that is furthest from the water.
- Stretch a second rope, parallel to the first and a short distance apart (50 cm is a suitable distance in this instance).
- Travel along the rope and record all the living things that are found in the narrow strip between the ropes.
- Use a key to indicate each type of organism found in the transect. Star fish might be represented by a star, anemones by crosses and chitons as circles. For very small and numerous organisms such as periwinkles or moss it may be necessary to indicate the area where the organisms are found (by shading the area, for example) rather than mark the location of each individual.

A transect can reveal information about factors that are important to a species' survival. On a rock platform, species that cannot tolerate drying out will be found only close to the low tide mark, whereas other species thrive further up the rock platform. They have adaptations to enable them to survive out of water for a number of hours and their distribution keeps them out of reach of any predator that is suited only to life in water.

Line transects provide information on the distribution of a species in a community.



INVESTIGATION 13.5

Drawing a transect

AIM: To use a transect to record the distribution of species in an ecosystem.

You will need:

two ropes, at least 50 m long. Ideally the rope should have markers every metre.
access to a natural environment or an area of the playground where there is a variety of plants

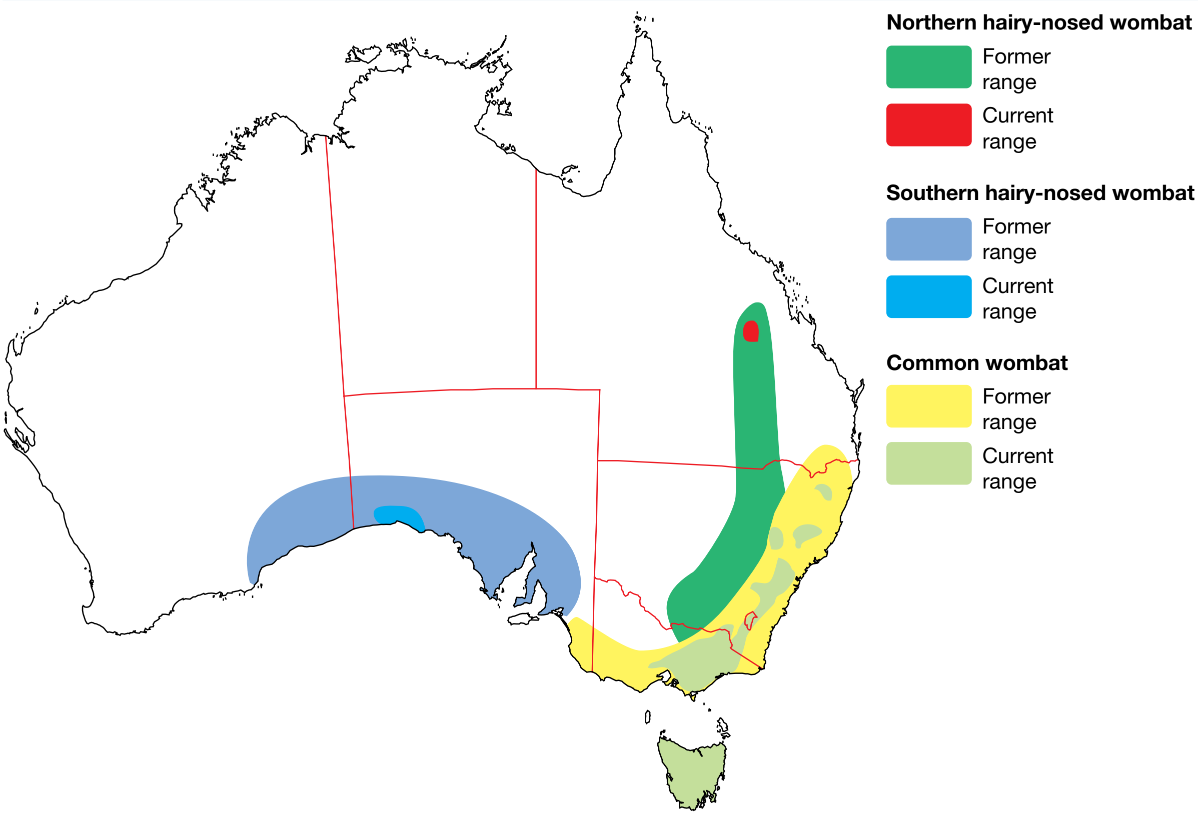
- Draw a rectangle 25 cm long and 5 cm wide on a piece of paper. This represents the transect. Mark a scale along one side of the rectangle.
- Stretch the two ropes, parallel to each other and 50 cm apart in the environment you are studying.
- Start at the zero mark and walk along the transect. In the rectangle you drew earlier indicate the plants you encounter. Use a different symbol for each type of plant. Make sure you include a key. For small plants such as grass or clover it is more convenient to draw an outline of the area where the plant is found rather than drawing each individual plant.

Discussion

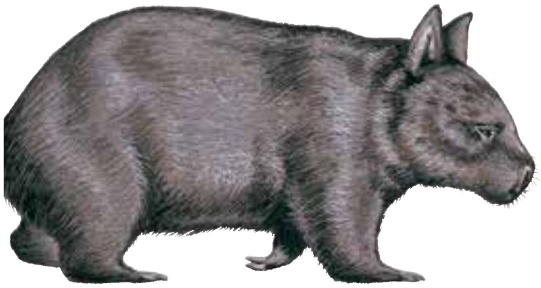
1. If the same scale had been used for the width and length of the transect, how wide should the transect be drawn?
2. What was the dominant type of plant in the transect you studied?
3. Is the transect you studied representative of the area surrounding the transect? Explain your answer.

Tracking the distribution of endangered species over time can provide information that may assist in making decisions about the best way to protect the species. The map below shows the present and past distribution of wombats. All wombats have a similar body shape, short legs and light brown fur, and they all spend a large part of the day in their burrow, but there are actually three different species of wombats in Australia: the southern hairy-nosed wombat, northern hairy-nosed wombat and common wombat.

Wombat species distribution



Southern hairy-nosed wombat
Smaller than Northern hairy-nosed wombat, but similar in appearance, it is the most endangered of all species of wombats.



Northern hairy-nosed wombat
It is the largest species of wombat, weighing up to 40 kg; it has softer fur, longer and more pointy ears, and a wide and hairy nose.

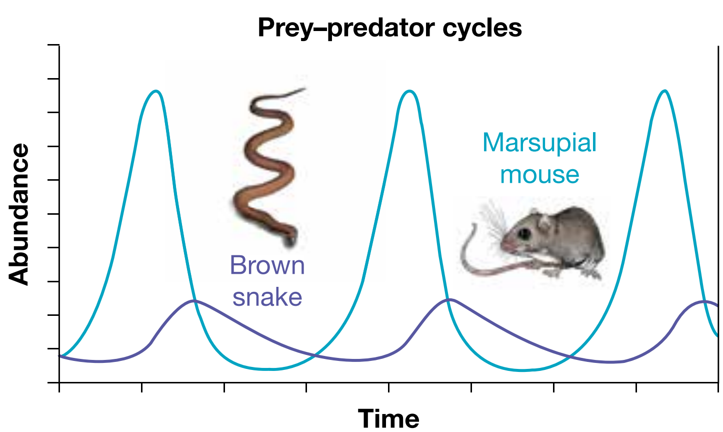
The northern hairy-nosed wombat is critically endangered and exists only in the Epping Forest National Park in Queensland. Preserving this national park is therefore critical to the survival of this species of wombat. The other two species of wombats have a bigger range and they are more common, although since European settlement their range has also decreased.

Common wombat
A medium-sized wombat that has small ears and coarse brown fur. Its nose is smaller and lacks whiskers.

13.7.2 Population fluctuations

In some instances it is important to study fluctuations in populations so we can get an idea of normal patterns and identify unusual rises and falls in populations. Fluctuations can also give us information about environmental factors that affect the size of populations. Seasonal changes and extremes of climate can impact on the amount of vegetation growing in an area. Grass, for example, generally grows faster in summer than in winter, although drought can severely reduce the amount of grass available to grazing animals. First-order consumer populations fluctuate in response to the availability of food. When food is plentiful they survive longer, have a better chance of reproducing and the offspring are more likely to survive to maturity. There is an increase in the population. If we plot the amount of vegetation in an ecosystem and the population of first-order consumers we find that they follow a similar pattern of rises and falls with a slight delay between the two populations. In turn, the second-order consumer population also follows a similar pattern with a time delay.

Populations of predators and their prey follow a cyclical pattern in response to seasonal changes in the environment.



13.7 Exercise: Remember and think

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Remember

1. **Define** the term ‘distribution’.
2. **Outline** the steps involved in constructing a transect.
3. **Explain** why it is important to study natural fluctuations in populations.
4. Which species of wombat is critically endangered? **Describe** its distribution.

Think

5. **Outline** some factors that might cause fluctuations in the amount of vegetation in an area and how this might impact on the animals that feed on this vegetation.
6. **Explain** why it is important to have information about the distribution of endangered species.

Skill builder

7. Study the graph on the previous page.
   (a) Imagine that a species that feeds on marsupial mice was introduced to the area. **Describe** the impact on the population of marsupial mice and brown snakes.
   (b) **Explain** why there is time delay between the rises and falls in the prey and predator populations.
   (c) **Explain** why the maximum number of brown snakes is significantly less than the maxiumum number of marsupial mice. Do you think this would always be the case reagardless of the predator and prey?
8. The table below shows how the number of echidnas and dingos changed over time in a particular area of bushland.

Year	Number of echidnas	Number of dingos
1990	90	12
1991	130	18
1992	210	30
1993	220	110
1994	100	180
1995	60	125
1996	55	59
1997	63	39
1998	66	39
1999	75	24
2000	78	28
2001	120	22
2002	160	24
2003	150	36
2004	60	60
2005	30	145
2006	22	90
2007	43	45
2008	48	27
2009	48	30
2010	72	27

(a) **Construct** a graph showing how the number of echidnas and dingos changed between 1990 and 2010.
(b) **Identify** the predator and prey. How can you tell from the graph?
(c) **Outline** what would happen to the number of echidnas if hunting caused dingo numbers to decrease dramatically.
(d) Echidnas feed on ants. If dingo numbers fell, outline the impact on the ant population. **Describe** the long-term impact on the echidna population.

9. Study the table at right.
(a) What does the table show?
(b) **Construct** a line graph of the data. Assume that the human population will reach 9 billion in 2045. Think carefully about the scale on the horizontal axis!
(c) **Describe** the shape of the graph.
(d) Suggest some reasons why the human population has grown exponentially rather than fluctuating over the last 2 centuries. Do you think this trend will continue? **Justify** your answer.

World population estimates milestones

Population (in billions)	Year
1	1804
2	1927
3	1960
4	1974
5	1987
6	1999
7	2011
8	2025
9	2045–50

Investigate

10. Tim Flannery is an Australian scientist who has been outspoken about the need to control population growth in Australia. Find out some of the arguments he has put forward in support of his views. You could begin your search by typing the key words 'Tim Flannery population growth' in a search engine.
11. Use the **Population clock** weblink in the Resources tab to find out how many people are on Earth now.

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Explore more with this weblink: Population clock

13.8 Inspired by traditional owners

13.8.1 A relationship with the environment

The arrival of European settlers in Australia marked the beginning of a period of rapid environmental damage. The first settlers had limited knowledge of the Australian climate and soil and attempted to apply agricultural practices suited for European conditions. The traditional inhabitants of the land had a far more harmonious relationship with their environment. We are only now beginning to appreciate how much European settlers could have learned from Aboriginal and Torres Strait islander people by taking an interest in their cultural and land management practices.

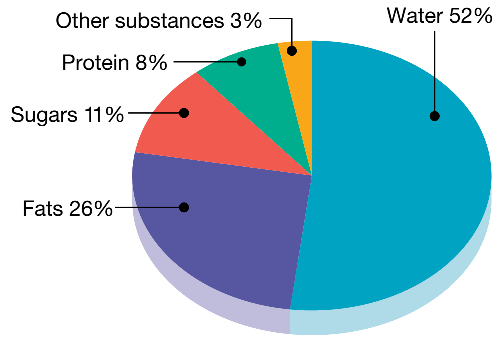
13.8.2 Hunting and gathering

The Aboriginal and Torres Strait Islanders people who were displaced by European settlers had a far greater sense of interconnectedness with their environment. Aboriginal people were hunter–gatherers. They did not farm the land or grow crops. Their survival was dependent on knowledge of the environment, the ability to identify edible plants, and to locate and hunt the animals they fed on. This knowledge was passed down the generations. Aboriginal people lived a nomadic lifestyle, using their knowledge of seasonal patterns in the availability of particular food sources and other resources to determine their path through the land. They hunted for almost any available animal. Aboriginal hunters knew the habits of the animals and kept a close watch on changes in the weather and plant growth. Their knowledge and skill allowed them to hunt very successfully.

Aboriginal Australians were also skilled gatherers of food. They obtained shellfish, nuts, berries, fruits, waterlily stems and roots, ants and much more. They knew which foods were poisonous and were able to

A witjuti grub — regarded as a delicacy in drier areas

Average body composition of a witjuti grub



Aboriginal bush tucker indudes a range of plant energy storage organs such as nuts, fruits and roots.

prepare some of these so that they could be eaten safely. Witjuti grubs are an example of highly nutritious bush tucker. They were regarded as a delicacy in drier areas. They could be obtained from the roots and stems of trees, especially the witjuti bush, after which they are named. Witjuti grubs are the white larvae of beetles and can be up to 13 cm long. They live off the sap of the trees that they live in. Witjuti grubs are very nutritious and are rich in protein, fat and sugars. They are also good sources of iron, calcium and water.

Some of the early European settlers and explorers learnt some of the traditional Aboriginal bush tucker skills, but most didn't bother. The explorers Burke and Wills died of starvation in central Australia on their return journey to Melbourne in 1861, even though seeds, roots and grubs eaten by the local Aborigines were available.

Water, of course, is scarce in most areas of Australia. They people knew how to obtain water in even the most arid areas. They knew where to dig in dry creek beds and were able to obtain water from tree roots, tree stems, frogs and other animals. They cut tree roots into small sections and sealed the ends with clay to store water.

Torres Strait Islanders also hunted and gathered much of their food from the local environment but unlike Aboriginal peoples they had some form of farming practices. Particular areas of land on their islands were allocated to different family groups.

13.8.3 Living sustainably

Some Aboriginal and Torres Strait Islander cultural practices ensured that hunting and harvesting were carried out in a sustainable manner. Certain animals and plants could be eaten only by certain groups of people such as elders or women. Other food could be hunted or collected only at particular times of the year, such as when a particular plant was in flower. When hunting, killing young animals or their mother was avoided.

Great emphasis was placed on taking only what was needed. Enough seeds had to be left to ensure that plants could regenerate. When eggs were collected from nests some of the eggs were left behind. After an area had been harvested it would be left alone for a number of months to give plants and animals a chance to build up again.

Unfortunately in more recent times customary law has not always been adhered to when hunting for bush tucker. This, together with the use of modern hunting weapons, is likely to have contributed to the decline in numbers of species such as emus, bustards and echidnas in Central Australia as well as dugongs and turtles in some coastal areas.

13.8.4 Dugong gone?

Dugongs are fully marine mammals, with a flattened tail and cow-like appearance. They are thought to be the source of myths about mermaids, and they feature in the creation stories of many Indigenous peoples across northern Australia. Dugongs are now considered endangered. Although they can live for up to 70 years, they have a slow reproductive rate, long gestation period and slow growth rate. Their coastal habitats are being destroyed, and they have been hunted for food and accidentally captured in fishing nets.

For some coastal Australian Aborigines and Torres Strait Islanders, dugongs have been a highly prized source of meat. In the past, white settlers were allowed to hunt them for food, hide and oil. However, it is now legal only for Indigenous peoples to hunt them, and only if they use traditional methods of hunting. Even with these restrictions, dugong populations in some regions are dwindling to dangerous levels.

HOW ABOUT THAT!

Was the megafauna hunted to extinction?

Australia was once populated by giant animals — the megafauna. Examples of Australian megafauna included the *Diprotodon*, a car sized wombat-like animal, *Procoptodon Pusio*, a 3 m tall flat faced kangaroo and *Thylacoleo carnifex*, a marsupial carnivore the size of a large dog. These species are now extinct. What led to their extinction is a great mystery. There is some evidence that the megafauna was hunted by early Aboriginal Australians. Bones with marks made by weapons have been found near Aboriginal artefacts. Was the megafauna hunted to extinction? Another theory links the extinction of the megafauna to climate change. Fossil evidence, including fossilised pollen, reveals that much of the Australian continent was once covered by lush rainforests. Over time these retreated and were replaced by grassland and dry schlerophyll forests (forests that contain mainly drought tolerant species such as eucalypts and banksias). Megafauna that fed on soft leaved rainforest species may have found their food supply dwindling. Fires were becoming more frequent as well. Some were naturally occurring, but others were deliberately lit. This also had a long-term impact on the vegetation. Perhaps all these factors contributed to some extent to the extinction of the megafauna.

13.8.5 Growing bush tucker

Many crop species currently grown in Australia could not grow without irrigation and the addition of fertilisers to the soil. These crops are not particularly well suited to Australia's dry and nutrient poor soils. Growing the type of plants indigenous Australians have used as a source of food for thousands of years makes a lot of sense as these plants have adaptations to cope with Australian conditions. Matthew Koop has taken on this challenge. He is a commercial quandong harvester. Quandongs are tangy-fleshed stone fruits native to Australia's central deserts and southern arid regions.

Matthew Koop — a quandong pioneer?

Quandongs

Kakadu plum trees may be another native plant that we could see growing in orchards in the future. Dave Boehme, a Darwin farmer, believes that this plant has the ability to be grown successfully in remote communities and may be a very successful indigenous horticultural project. Increased interest in bush foods may see many more of our Australian natives cultivated to become viable economic enterprises.

Darwin farmer David Boehme with one of the 100 native plum trees on his property

13.8.6 Healthy as well!

In 2009, the CSIRO produced a research report on the presence of 'health-enhancing compounds' in a variety of native herbs, spices and fruit samples. They reported that the 'bush foods' sampled were exceptionally rich sources of antioxidants, folate, iron and vitamins C and E.

Some of the findings of a 2009 CSIRO report on Australian native foods

'Bush food'	High in antioxidants	High in vitamin C	High in folate	High in iron
Kakadu plum	✓	✓	✓	
Quandong	✓		✓	✓
Tasmanian pepper leaf	✓		✓	✓
Lemon myrtle	✓		✓	
Australian desert lime		✓	✓	

13.8.7 A fiery start

Fire was important to Aboriginal Australians. Setting fire to the vegetation was a way of driving animals out of burrows and other hiding places, making them easier to hunt. It was also a land management tool. In much the same way that backburning is carried out today, Aboriginal Australians used to set fire to bushland at times when temperatures were lower and the vegetation was not too dry. This produced a low-intensity fire. Burning some of the vegetation in wetter periods meant that there was less of the easily combustible plant matter left by the time the seasons changed and the weather was once again hot and dry. With less fuel, the bushfires of the dry season had less intensity. This is the main reason that backburning is carried out by fire fighters today.

Aboriginal Australians set fire to only some areas of land. Other areas remained intact. This was important for hunting because animals would flee from the burning areas to the unburnt patches of land. Many of the animals were not hunted though and the unburnt areas provided them with shelter. The ashes from the fire increased the nutrient content of the soil in the burnt areas and new growth would appear soon after the fire, providing a source of food for the animals.

Over time species that had adaptations that enabled them to survive bushfires evolved. Some eucalypts have thick bark that burns poorly. Beneath the bark are structures called epicormic buds that begin to grow after most of the leaves of the tree have been burnt off. There are also eucalypt species that have woody undergound stems called lignotubers. Since they are in the ground they do not usually burn in a fire. They begin to grow after the fire, allowing the tree to regenerate. Some trees do not survive bushfires but their seeds do. The seed of **Banksia** are protected from fire by woody cone-like structures (they are actually not cones, but fruits). The heat of bushfires releases the seeds into the nutrient-rich, ash-covered soil.

Aborigines using fire to hunt kangaroos, a watercolour painted by Joseph Lycett around 1820

Epicormic growth from the trunk of a eucalypt tree after a bushfire

Regrowth of gum tree from an underground woody lignotuber

A woody *Banksia* fruit opened after a bushfire

CSIRO scientists have compared areas of Arnhem Land in the Northern Territory that are regularly burned to other areas. They have found that the areas that are burnt regularly have greater biodiversity. Some species that are in decline in other areas are doing well there. The scientists have advised some farmers on Australia's rangelands to set fire to patches of their land regularly. The farmers are encourged to burn areas that are overgrown by woody shrubs, and not use the area for grazing for two to three years after the burn. It is hoped that this technique will result in higher quality pasture over time.

13.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Use a dictionary to **define** the following terms: harmonious, interconnectedness, sustainability, biodiversity.
2. State where witjuti grubs may be found and what they look like, and suggest why they are described as being very nutritious.
3. **Identify** one important difference in the way that traditional Aboriginal and Torres Strait Islander people obtained food.
4. **Outline** why early settlers would have benefited from learning some of the traditional bush tucker skills.
5. **Describe** how Aboriginal Australians living in arid areas find enough water to survive.
6. **Identify** some reasons that have contributed to dugongs becoming endangered.
7. **Outline** three possible hypotheses for the extinction of Australia's megafauna.

8. **Outline** two reasons why Aboriginal people used to set fire to the vegetation.
9. **Distinguish** between epicormic buds and lignotubers.

Think

10. **Outline** why it was important for Aboriginal people to know the habits of animals.
11. **Explain** why having rules about the seasons during which certain animals could be hunted and plants harvested contributed to the sustainability of the lifestyle of Indigenous Australians.
12. **Explain** why growing and harvesting the fruit of plants that are native to Australia may be more sustainable than growing introduced species such as orange or apple trees.
13. **Explain** why it was important for Aboriginal people to burn only some areas of land and leave other areas unburnt.
14. A pie chart showing the average body composition of a witjuti grub is shown in this subtopic. Present the same data in the form of a divided bar graph.

Investigate, design and create

15. Find out and report on research into Australian native plants as a source of food or medicine. Display your findings in a brochure, story book or journal article.
16. What do you think about hunting dugongs? Who should be allowed to hunt them? How many should be taken, when and why? Research dugong hunting, then share your findings and opinions with your team. Organise a class debate on an aspect of dugong hunting.
17. Dugongs feature in the creation stories of many Indigenous peoples across northern Australia. Find out more about one of these stories
18. Use the **Bush foods extravaganza** weblink in the Resources tab to research examples of bush tucker recipes and create your own recipe book.

    CAUTION: Take food allergies into careful consideration when planning your recipes.

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Explore more with this weblink: Bush foods extravaganza

13.9 It's all about balance

13.9.1 Living sustainably

As the human population continues to grow, natural environments are being destroyed to make way for housing, farmland and roads. In an attempt to meet the needs of humans we can inflict irreversible damage on our environment. It does not have to be this way. With careful planning and creative thinking it is possible for humans to live more sustainably.

13.9.2 Forests under threat

Since the arrival of Europeans in Australia just over 200 years ago up to 70% of Australia's forests have been cleared to make way for cities, roads and farms and to harvest timber. Timber is a valuable resource. It is used as a building material and to manufacture furniture and other goods. A large portion of the wood harvested in Australia is turned into wood chip (small pieces of wood). Some wood chip is used to make particle board to make cheap furniture and a small amount is used in landscaping, but the bulk is shipped overseas and made into paper. Timber is a renewable resource — after trees are harvested more trees can grow back — but the techniques used to harvest the timber influence whether the process is sustainable.

When a renewable resource is used sustainably, it can regenerate at the same rate or faster than it is being used up. In the case of timber, whether an area is completely cleared of trees or only some trees are removed makes a huge difference to the time taken for the forest to regenerate.

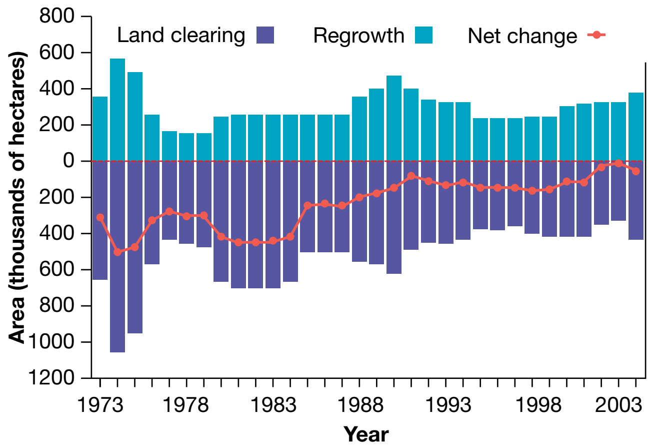
In Australia timber is harvested in the following ways:

- clear cutting: all or most of the trees are removed. The removal of all trees makes soil erosion more likely. The soil is not shaded, making it more difficult for new trees to become established.

- thinning: only some of the trees, usually the oldest, are removed. This technique is less damaging. The remaining trees produce seeds, reduce erosion, cut down wind and shade the soil. Getting trucks and other machinery to the trees can still have significant impacts on the forest though and it is important to select the right trees for cutting.
- the use of plantation timber: fast growing trees are planted on land that has previously been used to grow other crops or that was used as pasture. Provided that the land has not been cleared specifically for this purpose this technique is the most sustainable.

The technique used to harvest wood impacts on sustainability.

Are we getting better at harvesting timber sustainably?



13.9.3 What's in my chocolate?

In some instances, balancing the needs of humans with those of other species is as simple as replacing a cheap ingredient with another, slightly more expensive ingredient. Consumer awareness plays an important role in ensuring that manufacturers consider their impact on the environment.

Palm oil is obtained from the fruit of the oil palm tree. These trees are grown in large plantations in Malaysia and Indonesia. There are also plantations on the island of Borneo which is home to the endangered Bornean orangutan. Palm oil is used in many foods, creams and as a fuel. The increased demand for palm oil has motivated farmers to clear vast areas of rainforests to make way for oil palm tree plantations. As the forests are home to a number of endangered species the land clearing is driving these species to the brink of extinction.

Companies that use palm oil as an ingredient in the products they manufacture have been targeted by green groups such as Greenpeace and the Palm Oil Action Group. They aim to raise awareness about the impact of oil palm tree cultivation and encourage consumers to boycott products containing palm oil bought from suppliers linked with rainforest destruction. Some manufacturers have switched suppliers as a result of campaigns from action groups.

World demand for palm oil has led to the clearing of forests that are home to orangutans.

13.9.4 Meeting human demand for fresh water

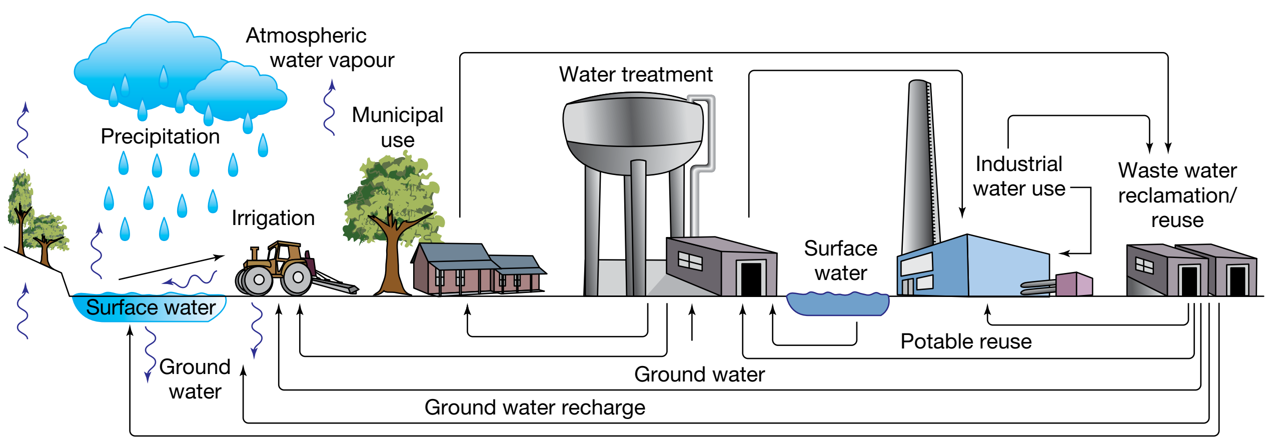
The Yarra River in Melbourne is close to its extraction limit; beyond that, it may stop flowing.

Australia is the driest inhabitable continent in the world. It has the lowest volume of water in rivers and the smallest area of permanent wetland. Many of its largest rivers are already at their maximum extraction rates (the amount that can be taken out of the river), beyond which flow rates cannot be sustained. Some, like the Murray and the Darling, have been over-allocated and their flow rates have been severely affected.

In 2014–15, Australia extracted 76 000 gigalitres of water from the environment. About 58 000 GL was used by the electricity and gas industry and most was returned to the environment. Of the 17 000 GL not returned to the environment, 60% was used for agriculture, 4% for mining and 3% for manufacturing industries. A **gigalitre** (GL) is a billion litres.

Australians are the third highest users of water per capita in the world, surpassed only by the United States and Canada. In cities, households use 59% of urban water. More than half of this is used for watering gardens and flushing toilets.

Water recycling possibilities



In 1997–98, the volume of **sewage effluent** processed was 1350 GL; most of this was discharged into the sea or rivers. Is this effluent too valuable to waste? Some of this effluent is now being recycled. If you have purple taps in your garden, the water that comes out of these taps is recycled. Several studies have shown that a high percentage of Australians are comfortable with the idea of using recycled water for irrigation, fire fighting, watering of parks and gardens, stock watering and toilet flushing. However, the acceptance level for drinking recycled water is not the same. In many new developments the outdoor taps and toilets are connected to recycled water pipes, while all other taps deliver non-recycled water.

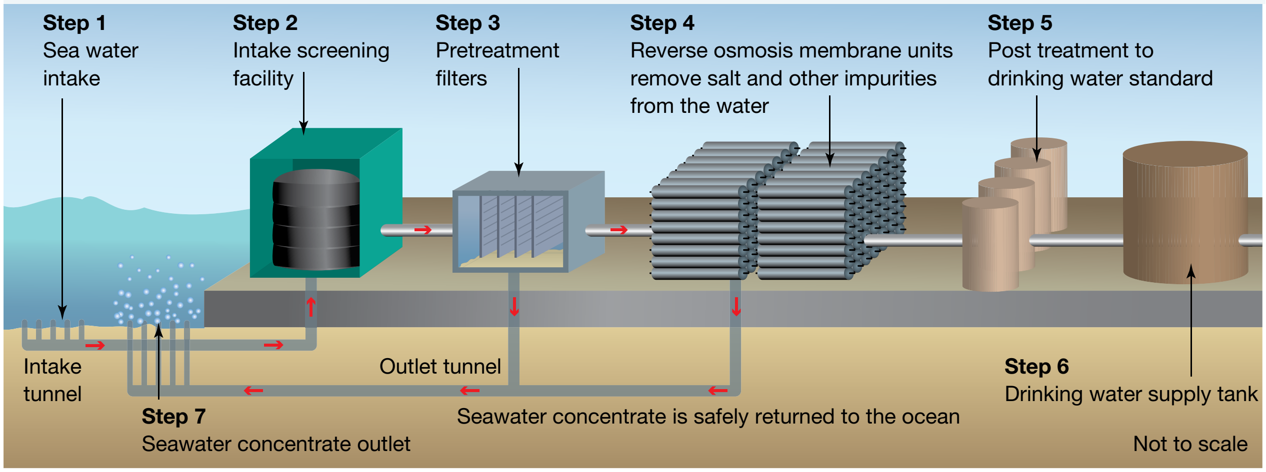
13.9.5 Desalination — the answer to our water shortage?

Fresh water is in short supply in Australia but the country is surrounded with sea water. Unfortunately, sea water is too salty to drink or water crops; however, a desalination plant can remove the salt from sea water. A desalination plant was built at Kurnell in Sydney in 2010. Are desalination plants the solution to our water shortage?

How does it work?

There are a few processes that can be used to remove salt from sea water. The Kurnell plant uses reverse osmosis. In osmosis, water moves through a semi-permeable membrane from an area where salt concentration is low to an area where salt concentration is high. The water moves in the direction that will 'even out' the concentration of salt on either side of the membrane. In reverse osmosis the water is being made to flow in the opposite direction using high pressure. The result is that very salty water is left on one side of the membrane and pure water is obtained on the other side.

An example of a desalination plant



Unfortunately, there are some environmental costs associated with reverse osmosis desalination plants. A huge amount of electricity is required to run the plant. If this electricity is produced by burning coal or another fossil fuel, large amounts of carbon dioxide gas (a greenhouse gas) are produced, thus contributing to global warming. In the case of the Kurnell plant, a new wind farm is being built in Bungendore in NSW, which should produce all the electricity needed to run the Kurnell plant without releasing any carbon dioxide gas.

Another important environmental issue is what to do with the salt that is produced. At the Kurnell plant, after the water passes through the reverse osmosis membrane, the fresh water is stored for use and the left-over water — which now contains about twice as much salt as normal sea water and is one or two degrees warmer — is dumped back into the ocean about 300 m off shore. This may have a negative impact on sea life living close to the salty water outlet.

13.9.6 Dealing with garbage in creative ways

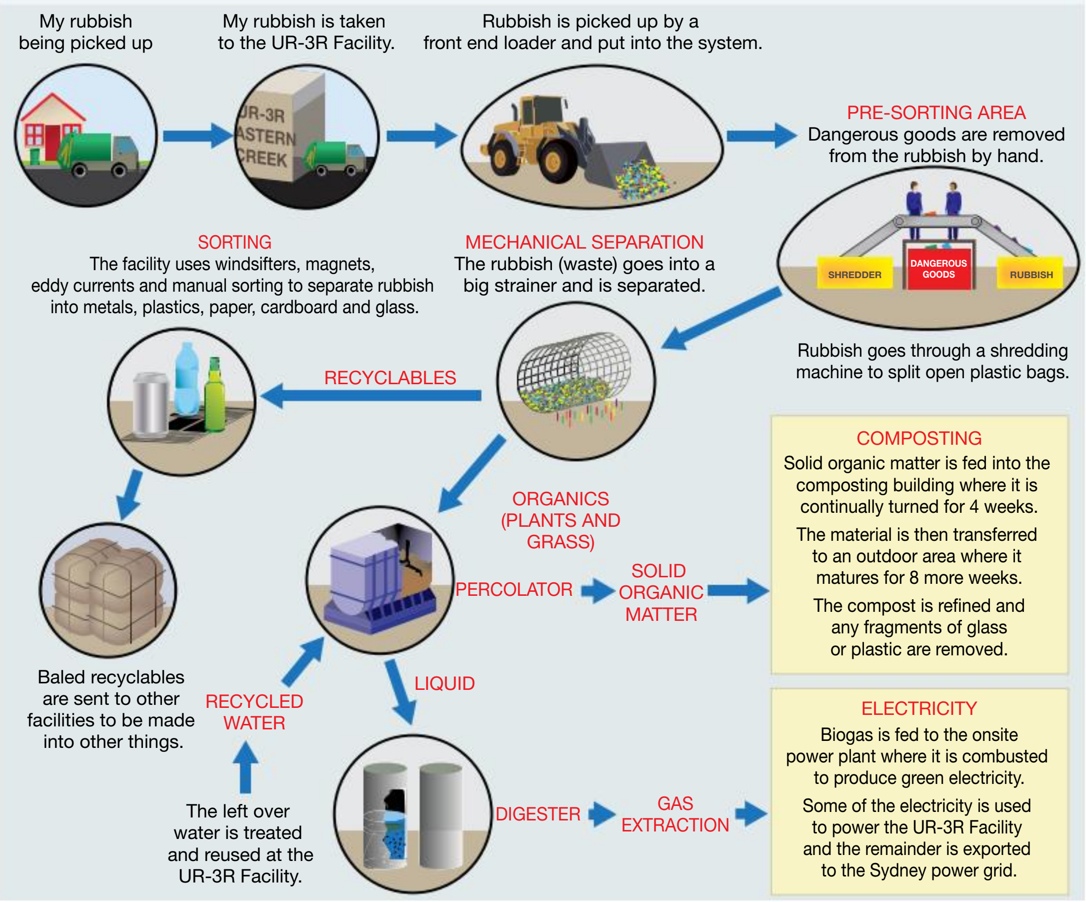
How much rubbish does your family produce each week? How big and how full is the bin you wheel out to be collected by the garbage truck each week? Now think about all the houses in Australia, each producing the same amount of garbage. That's a lot of rubbish and most of it ends up at the tip. With some creative thinking it is possible to put some of this rubbish to good use.

A large portion of the rubbish collected from households ends up in landfill. The rubbish is tipped into a hole and covered with dirt. Landfill sites take up a lot of space, and while they are in use the area around them is often smelly and unattractive to look at. They also release greenhouse gases. We can reduce the amount of rubbish that ends up in landfill by buying fewer goods, fixing broken items rather than replacing them and looking for products with little or no packaging. Many materials can be recycled or composted rather than ending up in landfill. Glass, aluminium and other metals, paper and many plastics can be made into new objects rather than being dumped at the tip. It is often tricky to separate recyclables though. Most councils issue residents with recycling bins but it can be difficult to get people to use the right bin and even the best intentioned people are often confused about which items can be recycled. Fortunately a little bit of clever science can help with this problem.

A high-tech approach to sorting rubbish

Facilities are now available for sorting the contents of your recyclables bin into paper, glass, aluminium etc. One Sydney facility, the UR-3R Facility, goes one step further — it sorts all household rubbish rather than just recyclables. The following diagram shows what happens to household rubbish at this processing plant. The council where this facility is used claims that it can reduce the amount of waste going to landfill by up to 80%, and that it can allow them to recover up to 7280 tonnes of recyclables that would otherwise end up in landfill. (*Source:* Fairfield City Council)

The UR-3R Facility reduces the amount of rubbish going to landfill.



Semakau landfill

In some parts of the world, very little land is available. The islands of Singapore are becoming very crowded, so crowded in fact that there is no space left on the islands to use as landfill. The solution has been to extend the land into the ocean to use as landfill space. The Semakau landfill is an offshore landfill and is attached to the main island of Singapore. To create the landfill, a 7 km bund (retaining wall) was built and the landfill was lined with a special membrane and clay so that the waste would not pollute the surrounding ocean. Most of the waste dumped in the landfill is ash as the rubbish produced in Singapore is incinerated to reduce the amount of space it takes up. The area is divided into cells. When cells are full they

The Semakau landfill is a clever solution to Singapore's lack of available landfill space. An area of the ocean has been enclosed for use as landfill space.

are topped up with soil and plants are grown over them. Many areas of the landfill have been opened to the public for recreational activities and tourists can take guided tours of the recovered areas to view the many birds and fish that have returned there.

13.9 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** some reasons for clearing forests?
2. List some uses of timber as a resource.
3. **Define** reverse osmosis.
4. **Identify** some ways we can reduce the amount of rubbish going to landfill.
5. In what way is the Semakau landfill different to other landfills?
6. **Outline** why waste is incinerated in Singapore.

Think

7. **Explain** why clear cutting is less sustainable than thinning when harvesting timber.
8. Products such as paper or floor boards are sometimes labelled as being made from plantation wood. Why might this be important to environmentally aware consumers?
9. Sometimes when forests are cleared wildlife corridors are preserved. These allow animals to travel from one area of bushland to another. **Explain** why this might be important.
10. **Discuss** the following statement: 'The council should charge waste disposal rates for each household per kg of waste they produce'.
11. In small groups make up a list of strategies that may help cut down the amount of rubbish sent to the tip by your school.

Skill builder

12. Study the graph Are we getting better at harvesting timber sustainably?
    (a) **Outline** the information shown by:
        (i) the green and blue columns
        (ii) the red dotted line
    (b) **Describe** the trend shown in the graph.
13. The following questions refer to the figure The UR-3R Facility reduces the amount of rubbish going to landfill.
    (a) **Identify** the types of items that could be separated from rubbish using a magnet.
    (b) **Identify** the steps of the rubbish separation process that are done manually (by people) at the UR-3R Facility.
    (c) What sorts of things would be separated from garbage using the big strainer?
    (d) **Outline** what happens to the recyclables collected at the UR-3R Facility.
    (e) **Describe** what happens to the solid organic matter that is separated from garbage at the UR-3R plant.
    (f) **Explain** what happens in the digester.

Investigate

14. To find out more about saving water in your home use the **Investigator** weblink in the Resources tab and be a home water investigator.
15. To take part in the waterworks adventure, use the **Waterworks** weblink in the Resources tab.
16. Use the **Water saver** weblink in the Resources tab and play the water saving game.

Design

17. List possible water-saving suggestions for your school. Design a poster or web page promoting these ideas.

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- **Explore more with this weblink:** Investigator
- **Explore more with this weblink:** Waterworks
- **Explore more with this weblink:** Water saver

13.10 Different perspectives

Science as a human endeavour

13.10.1 Opinions on environmental issues

People chaining themselves to trees, risking their lives to try to stop whalers, or marching through streets asking for action on climate change are stories that make the front pages of newspapers. Environmental issues are often complex though and there is usually more than one side to each story, as can be seen from the news snippets below. Each snippet is based on a news story.

PEACE SUMMIT CALLED OVER LOGGING DISPUTES

The Victorian government is setting up meetings to try to resolve conflict between the timber industry, the unions and environmentalists. The Wilderness Society would like to use the meetings to convince loggers to stop logging old growth forests and harvest plantation wood instead. Loggers argue that their industry provides 10 000 jobs in country towns and provides great social and economic benefits to these communities.

OWNER WANTS URANIUM-RICH LAND TO BE ADDED TO KAKADU

Jeffrey Lee, an Aboriginal traditional owner of thousands of hectares refused to sell his land to a French mining company for millions of dollars. Instead he donated the land to the federal government to become part of Kakadu National Park where he works as a ranger. He does not want the uranium mined because the land contains sacred sites, including burial sites. He feels it is his responsibility to look after the land and this is more important than the money.

View to Nourlangie from Anbangbang Billabong, Kakadu National Park, Australia

JAPAN TO RALLY PRO-WHALING NATIONS

Japan is organising a meeting of representatives from nations that support whaling. Commercial whaling is currently banned although some countries are exempted from the ban under certain circumstances. Japan is allowed to kill whales for research although it has been suggested that some of the meat from the whales killed for research has made its way to restaurants and stores. Anti-whaling groups have argued that all whaling should be banned. Supporters of whaling argue that controlled whaling of species of whales that are quite plentiful would not put them under threat.

Should all whaling be banned?

FRASER ISLAND'S DINGO FENCES 'WORKING'

In 2001 a fatal dingo attack on Fraser Island prompted the government to build fences around the townships, camping grounds and resort. Some locals argue that the fences are unsightly, impact on other species and are ineffective.

The main purpose of the fences is to stop dingoes getting access to food scraps and rubbish. When dingoes are fed by humans or eat human food scraps they stop hunting for their own food and become increasingly dependent on humans. Rather than fearing humans they seek them out, increasing the likelihood of attacks.

Some people argue that the fences, together with tough penalties for people caught feeding the dingoes, has resulted in dingoes starving. Some dingoes have also been shot because of fears that they may be violent towards humans. These two factors combined could lead to a great reduction in dingo numbers on Fraser Island.

Should there be dingo fences on Fraser Island?

The main roads on Fraser Island are shown on the map by red lines. Most of the accommodation is near these main roads. The townships, camping grounds and resort are fenced to discourage dingoes from feeding on scraps and rubbish. The dingoes still have access to most of the island.

13.10 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Outline** why the Wilderness Society is in conflict with loggers.
2. **Outline** some of the reasons to continue logging that have been put forward by loggers.
3. **Explain** why Jeffrey Lee wants his land protected from miners.
4. Suggest why there is suspicion that some of the whales caught by Japanese whalers are used for purposes other than scientific research.
5. **Outline** why dingo fences were built on Fraser Island.

Think and discuss

6. Removing resources such as uranium from the ground impacts on the environment. **Identify** some of the criteria governments should consider when deciding whether a resource should be mined.
7. Carry out a PMI on the following topics:
   (a) Logging of old growth forests should be illegal throughout Australia.
   (b) When land contains valuable resources such as uranium, petrol or gold the government should be allowed to force people off their land so the resources can be extracted.
   (c) Commercial whaling bans should be lifted.
   (d) People caught feeding dingoes should be given large fines.

Investigate

8. Find out why uranium is so valuable. What is it used for?
9. Use EBSCO or another database to locate news stories about the dingoes of Fraser Island. **Summarise** the key points in the articles you locate.
10. **Investigate** environmental issues affecting your local area. Looking through local papers or talking to your parents and teachers might help you identify some issues to research.

Create

11. Use the **Kakadu** weblink in the Resources tab to create a pamphlet, digital story or PowerPoint advertising Kakadu National Park to tourists.

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Explore more with this weblink: Kakadu

13.11 Review

13.11.1 Features of ecosystems

- **distinguish** between biotic and abiotic features of ecosystems **13.2**
- measure abiotic factors in an ecosystem **13.2**
- use the quadrat and capture–recapture methods to estimate the abundance of a particular species in an ecosystem **13.2**
- **define** the term ‘distribution’ **13.7**
- **interpret** population graphs **13.7**

13.11.2 Energy and materials in ecosystems

- **describe** the flow of energy in ecosystems **13.5**
- **interpret** biomass pyramids **13.5**

- **describe** the cycling of water in natural ecosystems 13.6
- **recall** word and symbol equations for photosynthesis and respiration 13.4
- **outline** the role of chlorophyll in photosynthesis 13.4
- **account for** the fact that ecosystems can exist in very deep oceans where no light is available for photosynthesis 13.4
- **extract** information from food webs 13.5
- **describe** the phosphorus and nitrogen cycles 13.6
- **outline** the main processes involved in the carbon cycle 13.6

13.11.3 Inspired by traditional owners

- **describe** Aboriginal and Torres Strait Islander practices that have a focus on sustainable harvesting of natural resources 13.8
- **explain** why there is renewed interest in the use of controlled fires as a land management practice in some parts of Australia 13.8

13.11.4 Environmental issues

- **describe** some strategies to reduce the amount of rubbish ending up in landfills 13.9
- **describe** some creative solutions to dealing with rubbish 13.9
- **evaluate** some strategies for addressing the shortage of fresh water in Australia 13.9

Individual pathways

ACTIVITY 13.1	ACTIVITY 13.2	ACTIVITY 13.3
Revising ecosystems	Investigating ecosystems	Investigating ecosystems further
doc-10679	doc-10680	doc-10681

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FOCUS ACTIVITY

Using the information in the **NOVA** weblink in the Resources tab as a starting point, create a pamphlet to convince the Australian public that conservation attempts are worth the effort. Your pamphlet should include information about Australian species that have been brought back from the brink of extinction. Include photos where appropriate.

Access more details about focus activities for this topic in the Resources tab (doc-10678).

assessON

13.11 Review 1: Looking back

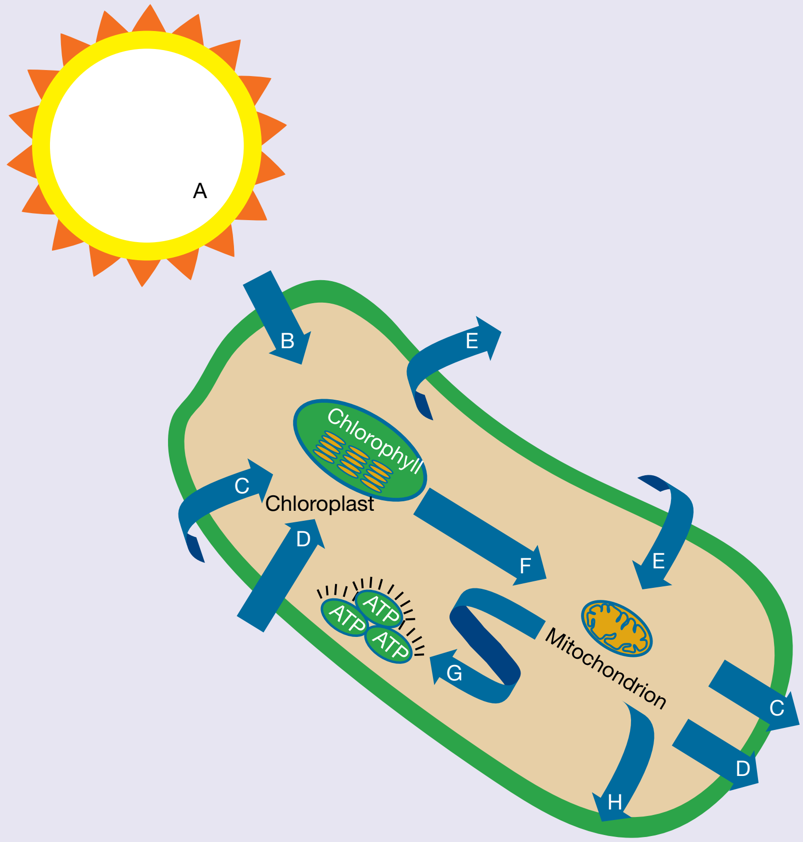
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

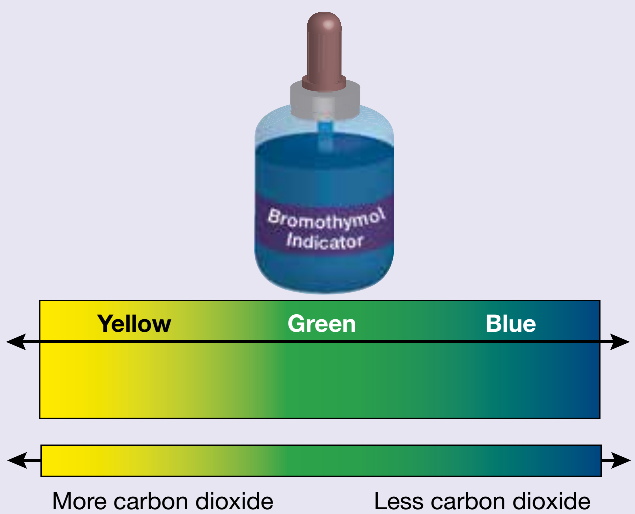
1. **Explain** why field work is a really important component of Ecology.
2. A rainforest and a rock platform are both examples of natural environments.
   (a) **Compare** three abiotic factors for these two environments.
   (b) **Describe** one biotic factor that might impact on the growth of plants in a rainforest.

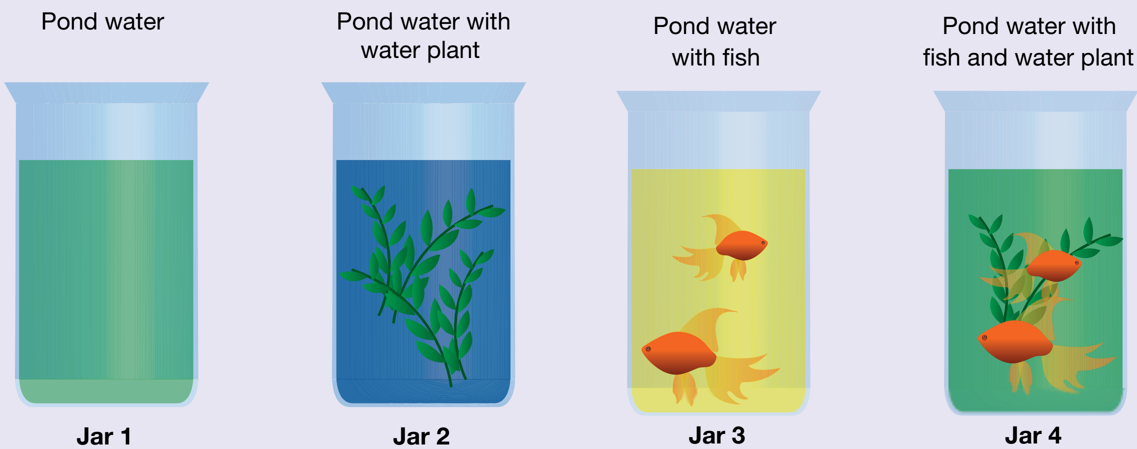
3. **Describe** how you could estimate the abundance of limpets on a rock platform at low tide. (*Note:* Limpets do not move much while the tide is low.)
4. The diagram at right shows a chloroplast and a mitochondrion in a plant cell.
   (a) Which energy conversion takes place in the chloroplast?
   (b) Which energy conversion takes place in the mitochondrion?
   (c) The arrows on the diagram at right show the flow of energy and substances into and out of the cell. Choose words from the word bank below that are represented on the diagram by the letters A–H.

   Word bank: water, oxygen, sun, carbon dioxide, heat energy, chemical energy, light energy, glucose.

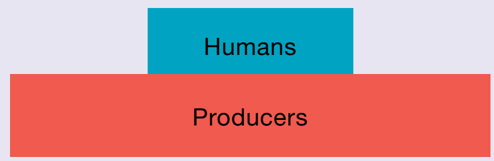


5. If someone said to you: 'If all photosynthesis on Earth stopped, humans would eventually become extinct', would you agree or disagree? **Justify** your answer.
6. Bromothymol blue is an indicator that changes colour in different concentrations of carbon dioxide.
   During an investigation of photosynthesis and respiration, an experiment was conducted to investigate energy conversions in a fish and in a water plant in pond water.
   Four jars of pond water collected from the same location were used (see next page). Bromothymol blue (10 drops) was added to each jar. All four jars were placed in a sunlit position in the classroom.
   (a) In which jar is aerobic respiration occurring? **Justify** your answer using the colour of the bromothymol blue in the water.
   (b) In which jar is photosynthesis occurring? How do the results support this?
   (c) In which jar are both respiration and photosynthesis occurring? **Explain** your answer.
   (d) Which jar was the control? **Explain** why it was necessary to set this jar up.

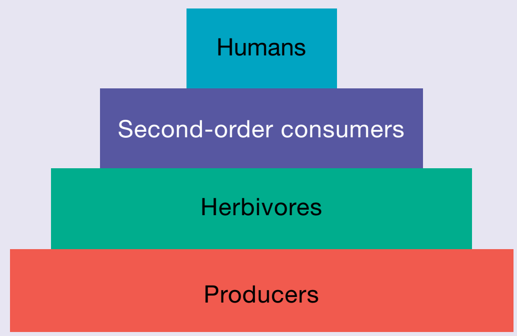




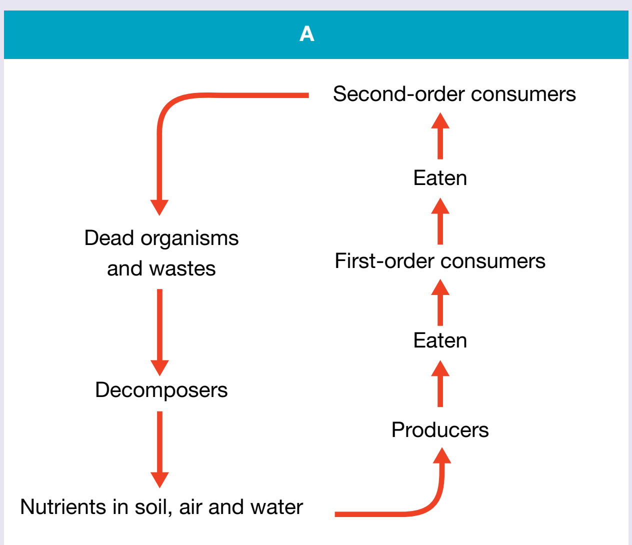
7. The size of the bars in the two pyramids on the right represents the number of organisms supported at each trophic level in two different farming communities. **Interpret** the pyramids to answer the following questions.
   (a) Copy the two pyramids into your workbook. Next to each pyramid, write down the names of, or sketch, organisms that could be represented at each of the trophic levels below humans.
   (b) Which ecosystem supports more humans?
   (c) Could the pyramids represent energy as well? **Explain** your answer.
   (d) Which community wastes less energy as it flows from producers to humans?
   (e) Apart from numbers and energy, what other quantity can be represented by an ecological pyramid?
8. **Interpret** the diagram below to answer the questions that follow.

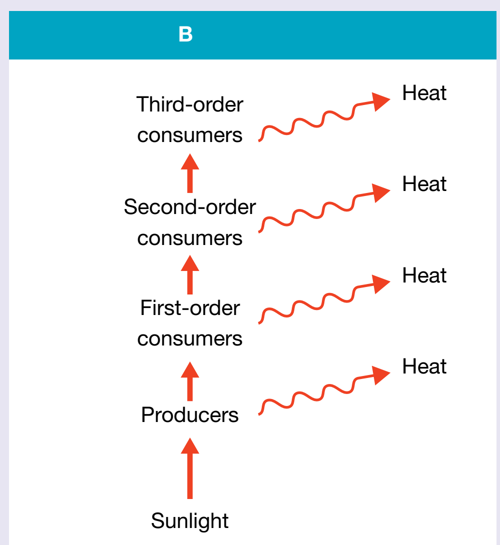


Community 1



Community 2



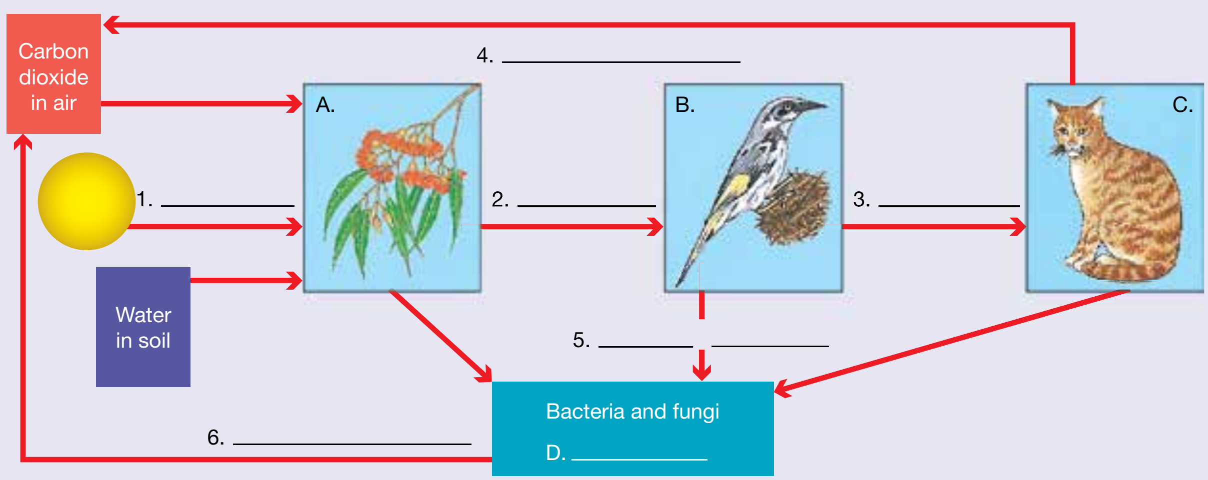


(a) Which box represents energy flow?
(b) Which box represents the cycling of matter?
(c) Copy the diagram and illustrate the flow or cycle by adding arrows between the words in each box. Use arrows to show the movement of matter or energy in each diagram.
(d) Label the boxes as ‘Flow of energy’ and ‘Cycling of matter’.
(e) How is the flow of energy different from the cycling of matter?
(f) How is the flow of energy similar to the cycling of matter?

9. Some Aboriginal and Torres Strait Islander cultural practices focus on the sustainable harvesting of resources from the environment. **Define** the term sustainable and give three examples of such cultural practices.
10. Prior to the arrival of Europeans, how was fire used for hunting by Aborigines? **Explain** why there is renewed interest in the use of fire as a land management practice.
11. **Describe** an environmental problem you have studied and a possible solution for this problem.
12. Use an example you have studied to **explain** why different groups in society might have very different opinions about environmental issues.

Test yourself

1. Which of the following is a biotic factor?
   (A) Light intensity
   (B) Soil moisture
   (C) Soil pH
   (D) Presence of fungus of the genus mycorrhiza in the soil **(1 mark)**
2. Which gas is released in photosynthesis?
   (A) Oxygen
   (B) Carbon dioxide
   (C) Nitrogen
   (D) Hydrogen **(1 mark)**
3. Copy and complete the diagram below by filling in:
   (A) The types of organism labelled with the letters A, B, C and D **(1 mark)**
   (B) The processes labelled with the numbers 1–6. You may use words more than once. **(6 marks)**
4. Which of the statements below is correct?
   (A) In natural ecosystems both matter and energy are recycled.
   (B) In natural ecosystems energy flows and matter is recycled.
   (C) In natural ecosystems both matter and energy flow.
   (D) In natural ecosystems matter flows and energy is recycled. **(1 mark)**



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Complete this digital doc: Worksheets 13.5: Ecology puzzle (doc-12827)

Complete this digital doc: Worksheets 13.6: Ecology summary (doc-12828)

TOPIC 14 Global systems

14.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

14.1.1 Why learn this?

We are living in the anthropocene era — an age in which humans are dominating and disrupting many of our planet's natural systems. Is it time for us to recognise our effect and take responsibility for our actions? How much further can we push our global life-support systems? Within the next century, will our species be a mere footprint on what is left of Earth?

LEARNING SEQUENCE

Is our stewardship of Planet Earth on borrowed time? Is it too late to reverse the damage that humans have done or can we yet pull our species back from the brink of calamity?

Are you involved in causing the sixth mass extinction?

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

There have been suggestions that humans have unleashed the sixth known mass extinction in Earth's history. Human activities such as destroying habitats, overhunting, overfishing, introducing species, spreading diseases and burning fossil fuels are thought to be the key triggers of this mass destruction.

There have been five other mass extinctions recorded over the past 540 million years. Fossil evidence suggests that in these other mass extinctions at least 75 per cent of all animal species were destroyed. These extinctions are thought to have been caused by climate changes.

Scientists suggest that, prior to our expansion about 500 years ago, mammal extinctions were very rare. On average, only two species died out every million years. In the last 500 years, however, at least 80 of 5570 mammal species have become extinct. This is alarming in terms of biodiversity.

Of concern is the increasing list of critically endangered or currently threatened species. If these species become extinct and biodiversity loss continues, scientists suggest that the sixth mass extinction could arrive within 3 to 22 centuries. While this may seem like a long timeframe compared with all but one of the other five mass extinctions, it is considered by paleobiologists to be fast.

The most abrupt mass extinction, in which an estimated 76 per cent of species (including dinosaurs) were wiped out, occurred around 65 million years ago (at the end of the Cretaceous period). It is generally accepted that the cause of this was the crashing of a comet or asteroid into our planet, resulting in firestorms and dust clouds, which in turn led to global cooling. The four previous mass extinctions are estimated to have taken hundreds of thousands to millions of years as they were due mainly to naturally caused global cooling or warming.

Investigate, think and discuss

1. (a) List examples of human activities that are suggested to be key triggers for the sixth mass extinction.
   (b) Do you agree or disagree with this suggestion? Justify your response.
2. (a) Compare the rate of mammal extinction prior to and after human expansion.
   (b) Suggest what this has to do with biodiversity.
   (c) Suggest why scientists are concerned about loss of biodiversity.
3. (a) Research and construct summary reports on the five recorded mass extinctions.
   (b) Select one of the mass extinctions and write a story that could be acted out by characters living during the time of the mass extinction. Be sure to include examples of biodiversity prior to the mass extinction and then the biodiversity loss during or at the end of the mass extinction.
   (c) Communicate your story to others using multimedia (e.g. animation, slowmation or documentary), cartoons or songs.

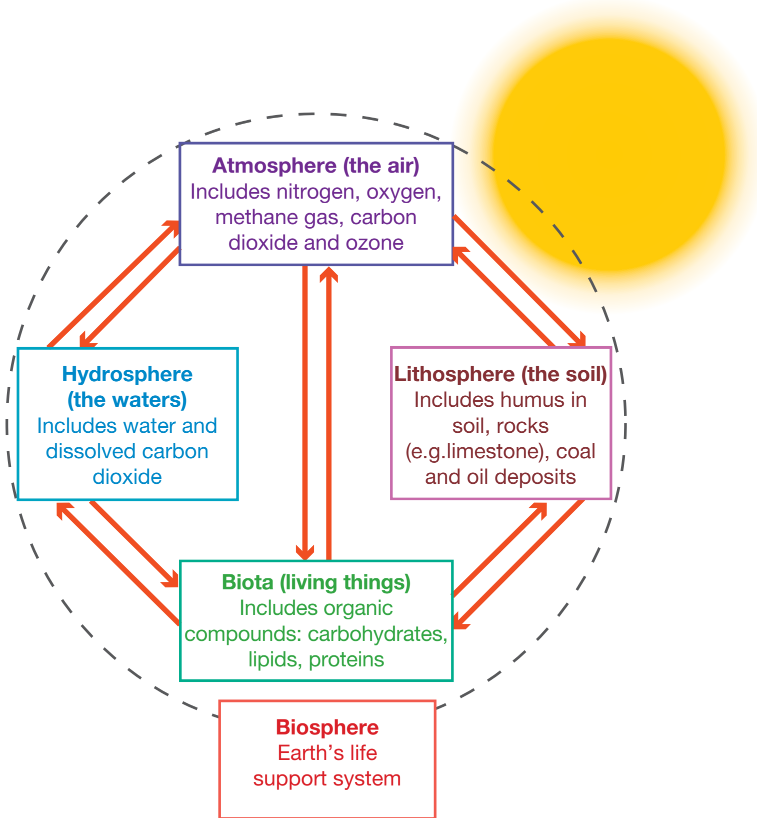
14.2 Revisiting cycles and spheres

14.2.1 The biosphere

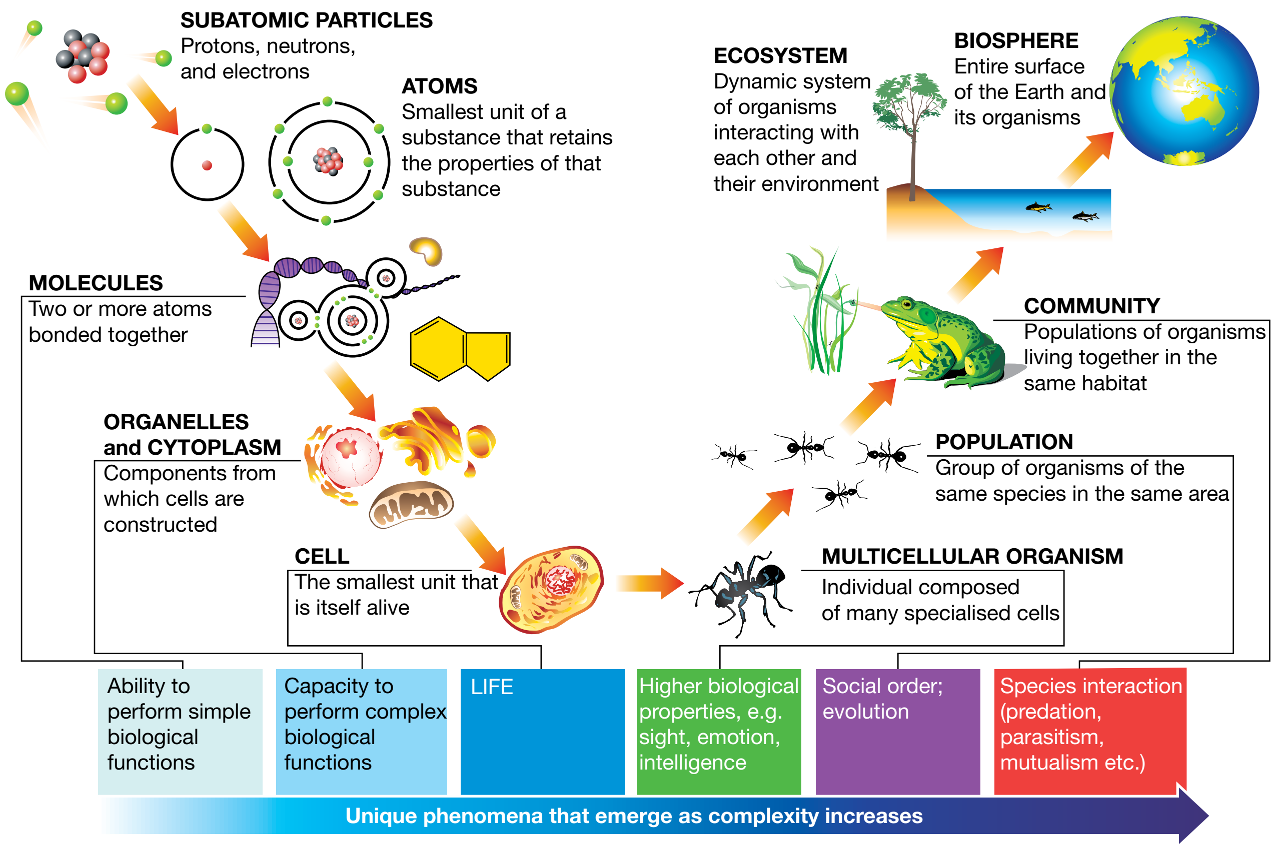
All habitats on Earth are located in what could be considered a life-support zone. This thin layer of our planet includes the **atmosphere**, the ocean depths, and the upper part of Earth's crust and its sediments.

The **biosphere** is the life-support system of our planet. It consists of the atmosphere, lithosphere, **hydrosphere** and **biota** (living things), the interactions between them, and the radiant energy of the sun. The biosphere includes all of the ecosystems on Earth. Interactions within the biosphere include the cyclical movement of essential elements such as carbon, nitrogen and phosphorus.

The biosphere can be considered Earth's life-support system.



There is pattern, order and organisation within organisms and also within the environments in which they live.



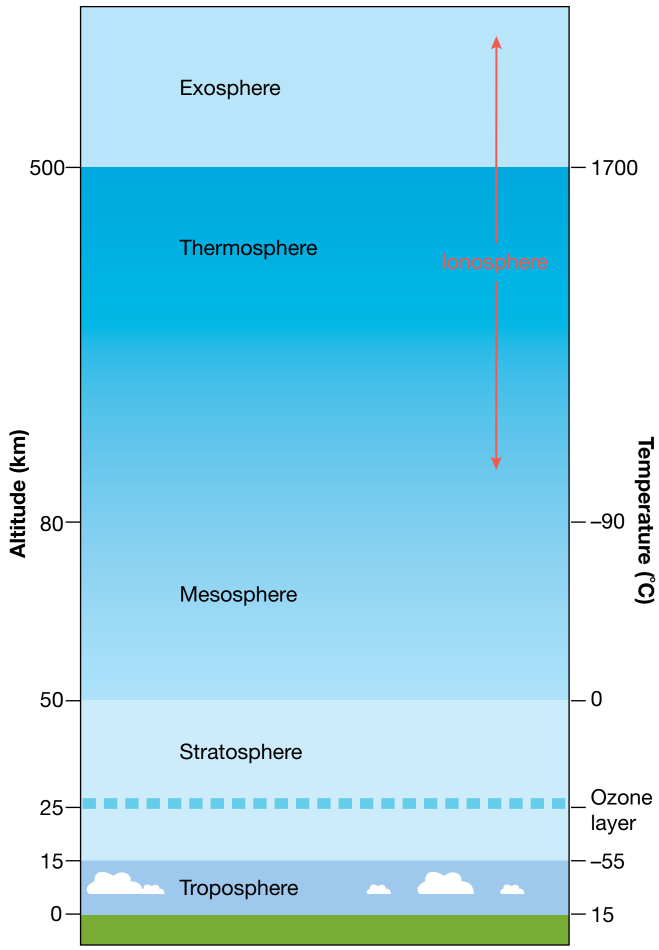
14.2.2 The atmosphere

The Earth's atmosphere is divided into the **troposphere** (lower atmosphere) and the **stratosphere** (upper atmosphere). The troposphere is around 6–17 kilometres depending on your latitude (how close you are to Earth's equator or the poles). The stratosphere is about 50 kilometres thick and contains an area known as the **ozone layer**. While this layer allows visible and infra-red radiation from the sun through, it absorbs ultraviolet (UV) radiation. This reduces the amount of damaging UV radiation reaching Earth's surface.

Human activity and the atmosphere

Chlorofluorocarbons (CFCs) have been used as coolant agents in refrigerators and air conditioners, as propellants in aerosols, and as industrial solvents. Their use has resulted in an increased amount of these compounds being released into the atmosphere. Once in the stratosphere they are broken down into chlorine atoms, which destroy ozone molecules. This has led to depletion of areas of the ozone layer, increasing the amount of damaging UV rays that get through and causing damage to living organisms.

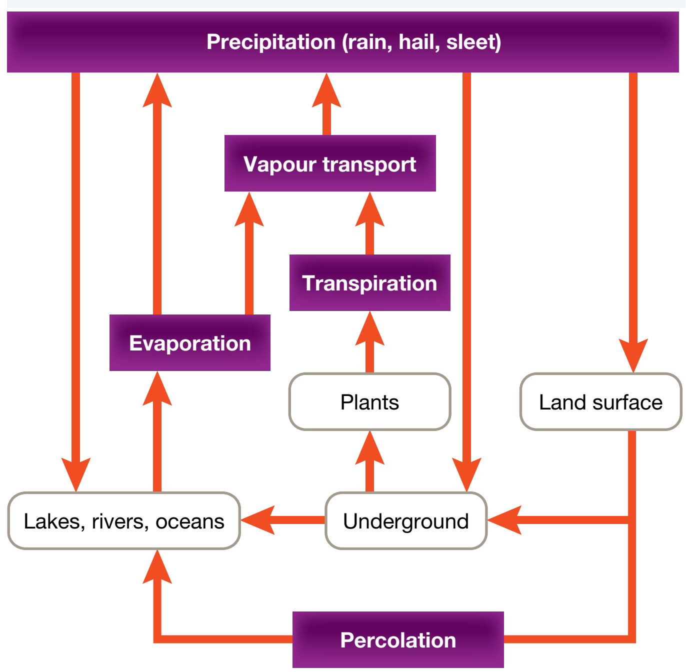
Layers in the Earth's atmosphere



14.2.3 The hydrosphere

The waters of our planet make up the hydrosphere. The simplified figure of the water cycle shown at right describes how water moves through the biosphere.

A simplified view of the water cycle



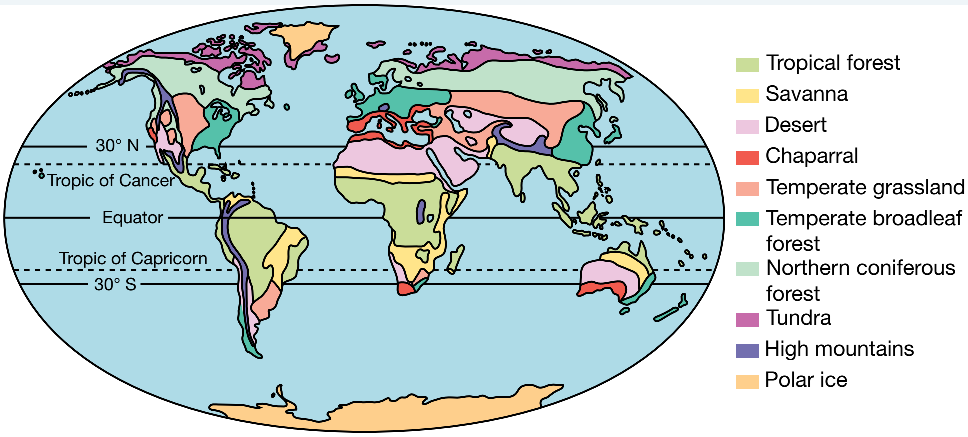
Human activity and the hydrosphere

Toxic or industrial wastes and untreated sewage in water systems have made their way into rivers, bays and the ocean, which has had a direct impact on the hydrosphere. Toxins can move along food chains, in some cases being biologically magnified — getting more concentrated — as they move up the chain. While some of these wastes are purposefully dumped, in other cases they enter the water system in run-off from the land or are washed out of the atmosphere in rain.

14.2.4 The lithosphere

The Earth's soil and rocky crust, along with the uppermost section of the mantle on which they sit, make up the lithosphere. It is within this

The type of dominant vegetation within biomes is influenced by environmental factors.



sphere that **igneous**, **sedimentary** and **metamorphic rocks** are formed, broken down and changed from one type to another.

The land surface of our planet is divided into regions called **biomes**. The criterion used to divide regions into biomes is the dominant vegetation type. Environmental factors (such as latitude, temperature and rainfall) influence the type of vegetation that can survive in a particular area and so can be used to predict the type of biome that may exist there. The figure at right shows examples of Earth's biomes and the relationship between the distribution of vegetation types and temperature and rainfall.

Human activity and the lithosphere

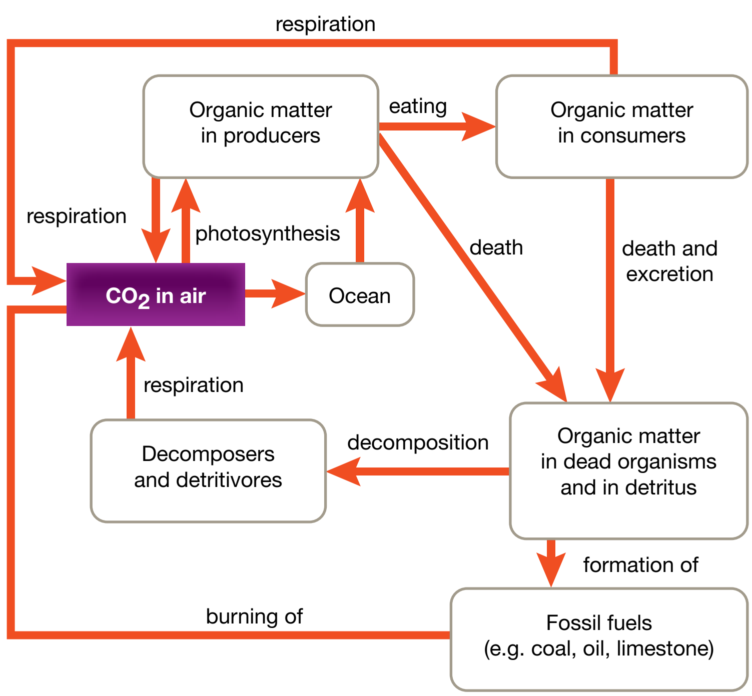
Overstocking, soil exhaustion, salinity, pesticides, unstable landfill, salinisation, toxic seepage, excessive clearing, chemical emissions, deforestation and soil erosion can all be very destructive to the lithosphere. Overgrazing and deforestation may also result in desertification. They can have detrimental effects on habitats and resources and hence the survival of organisms within the ecosystem that they are affecting.

14.2.5 The carbon cycle

Carbon is present in various compounds within the biosphere. It can be found in the hydrosphere as dissolved carbon dioxide, and in the lithosphere as coal or oil deposits and as rocks such as limestone. Within the atmosphere it may be present as methane or carbon dioxide, and within living things it may occur as proteins, carbohydrates or lipids.

The carbon cycle models how carbon cycles through the biosphere. Carbon moves from the non-living atmosphere to living things when carbon dioxide is absorbed by photosynthetic organisms (such as plants). A simplified version of the carbon cycle is shown at right. Can you see the areas within the cycle where the non-living parts of the biosphere (atmosphere, lithosphere and hydrosphere) and the living parts (biota) are interacting?

A simplified view of how carbon is cycled within an ecosystem



HOW ABOUT THAT!

The term *lithosphere* comes from the Greek words *lithos*, meaning 'stone', and *sphaira*, meaning 'globe' or 'ball'.

Excessive clearing and deforestation affect the lithosphere.

Human activity and the carbon cycle

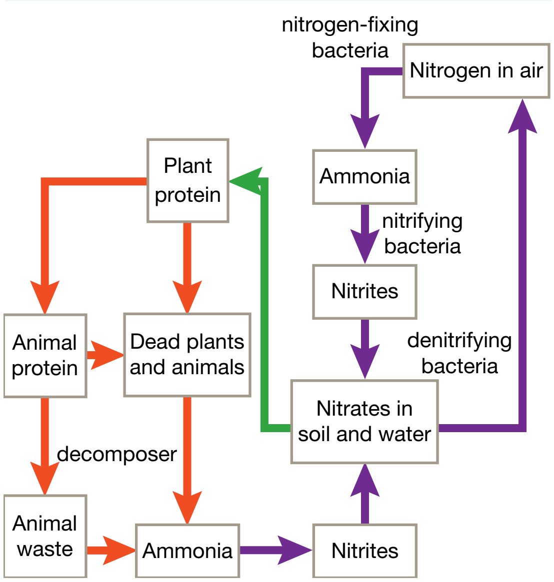
Increased human populations and industrialisation have resulted in an increase in the burning of fossil fuels. Human activity has also led to changed patterns in land use and deforestation. It has been argued that these have all contributed to an increase in the carbon dioxide that has been added to the atmosphere. Increased levels of this greenhouse gas have contributed to the enhanced greenhouse effect and global warming. Increased global temperatures may result in melting of ice caps, rising of sea levels, coastal flooding and unusual weather patterns. These events may threaten the survival of life in many ecosystems.

14.2.6 The nitrogen and phosphorus cycles

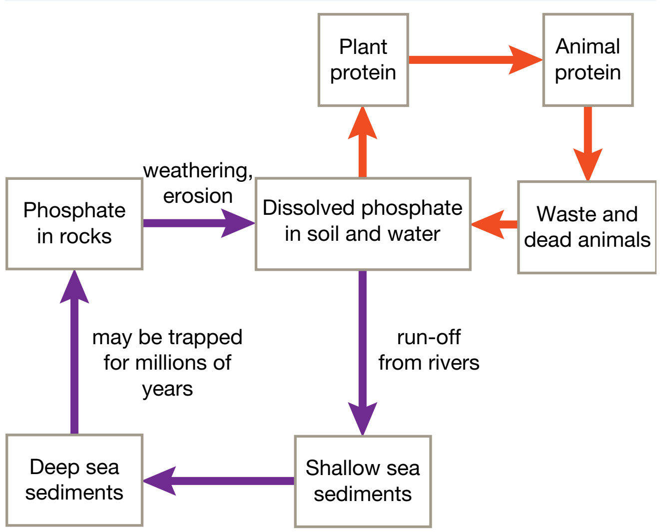
The nitrogen cycle models how nitrogen cycles through the biosphere. A simplified version of this cycle is shown in the figure below. Can you see the areas in which the non-living parts of the biosphere and the living parts are interacting with each other?

The phosphorus cycle models how phosphorus moves from the lithosphere to the hydrosphere and then through food chains and back.

A simplified view of how nitrogen is cycled within an ecosystem



A simplified view of how phosphorus is cycled within an ecosystem



Human activity and the nitrogen and phosphorus cycles

Large amounts of chemical fertilisers rich in nitrogen and phosphorus have been used on agricultural crops to enhance their growth. The excessive use of these fertilisers has led to considerable quantities of nitrogen and phosphorus moving into lakes, bays and other water systems. In some instances this has led to eutrophication and death of organisms within those ecosystems.

Industrial wastes that contain nitrogen oxides have also been released into the atmosphere. Nitrogen oxide can react with water vapour to form nitric acid and then leave the atmosphere via the water cycle as acid rain. This can change the acidity of water systems, resulting in death of organisms.

The environment of this magpie lark has been affected by excessive algal growth.

14.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

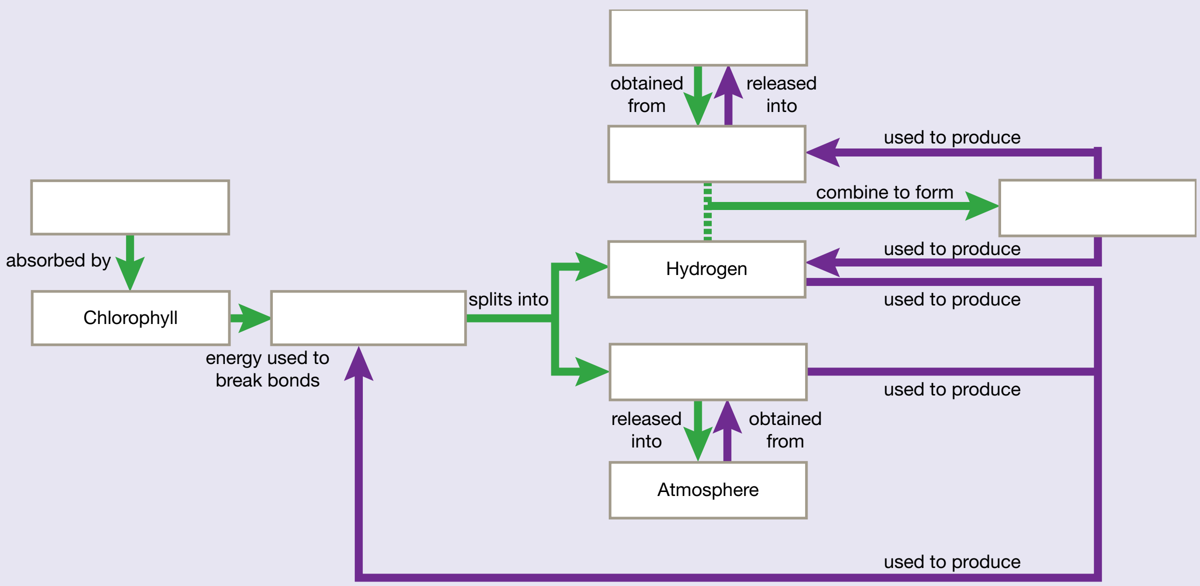
Remember

1. **Identify** the term used for the life-support system of our planet.
2. State the four components that make up the biosphere.
3. Suggest how the water, carbon, nitrogen and phosphorus cycles are linked to the biosphere.
4. Suggest what is meant by the term *biota*.
5. **Construct** a diagram to show the relationship between the atmosphere, lithosphere, hydrosphere and biota.
6. Is the ozone layer in the troposphere or the stratosphere?
7. **Outline** the importance of the ozone layer to life on Earth.
8. State examples of four gases that you would find in the atmosphere.
9. Suggest why an increase in CFCs in the atmosphere is of concern.
10. **Identify** the cycle that is most relevant to the hydrosphere.
11. State examples of precipitation.
12. Provide examples of parts of the Earth that make up the lithosphere.
13. **Identify** the criterion used to divide regions into biomes.
14. Into which sphere would you place biomes?
15. Provide examples of two environmental factors that contribute to the type of biome that exists in a particular area.
16. Suggest how photosynthesis, cellular respiration and burning of fossil fuels link into the carbon cycle.
17. **Distinguish** between nitrogen-fixing, nitrifying and denitrifying bacteria.
18. **Construct** a figure to summarise the:
    (a) carbon cycle
    (b) nitrogen cycle
    (c) phosphorus cycle
    (d) water cycle.

19. Suggest a link between the following cycles and the biosphere.
    (a) Carbon cycle
    (b) Nitrogen cycle
    (c) Phosphorus cycle
    (d) Water cycle
20. **Outline** effects of human activity on the:
    (a) atmosphere
    (b) lithosphere
    (c) hydrosphere
    (d) carbon cycle
    (e) nitrogen and phosphorus cycles.

Think

21. Suggest a link between your DNA and the phosphorus cycle.
22. The figure below shows a more detailed view of how processes such as photosynthesis (green arrows) and cellular respiration (purple arrows) are involved in interactions between the atmosphere (exchange of gases) and living things. Copy and complete the figure below, inserting the following words: atmosphere, light energy, glucose, oxygen, water, carbon dioxide.



Create

23. **Construct** a model of one of the following cycles to demonstrate its interactions within the biosphere: carbon, nitrogen, phosphorus or water.
24. Create a picture storybook or animation to show how human activity affects global systems.

Investigate

25. An ecological footprint is a measure of how much biologically productive land your activities require.
    (a) Suggest how the theory behind ecological footprints links to the biosphere.
    (b) Do you think that an awareness of your ecological footprint will have an environmentally positive effect on your future behaviours? Explain.
    (c) Do you think that ecological footprints really do show what they claim to? Justify your response.
    (d) Do you think that knowledge of ecological footprints is effective in changing behaviour and lifestyles to be more environmentally friendly? Justify your response.
    (e) Research and report on water and carbon footprints. How are they similar? How are they different?

26. What are superphosphate fertilisers and why are they used? Research these fertilisers and communicate your findings in a PMI chart or SWOT analysis diagram.
27. Where did the phosphate from your last meal come from? Why is phosphate important in your diet? What happens to the phosphate when it leaves your body during digestion?
28. Is Australia addicted to phosphate? **Investigate** this question and provide data to support your opinion.
29. **Investigate** and report on why most of our phosphate is being exported.
30. Where does phosphate come from? Can our phosphate supplies run out? What happens if we can't get the phosphate that we need? Research and report on these questions.
31. Select a system or cycle discussed in this subtopic and investigate and report on how human activity affects it.
32. **Investigate** the carbon, nitrogen, phosphorus or water cycle and construct a model to simulate how it works and why it is important to life on Earth.
33. Use the **Peak phosphorus** weblink in the Resources tab to watch a video about how phosphorus is a major part of our food production.

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Explore more with this weblink: Peak phosphorus

Complete this digital doc: Worksheet 14.1: Nature's time machine (doc-12829)

Complete this digital doc: Worksheet 14.2: Cycles in nature (doc-12830)

14.3 Patterns, order and organisation: climate patterns

14.3.1 Climate patterns

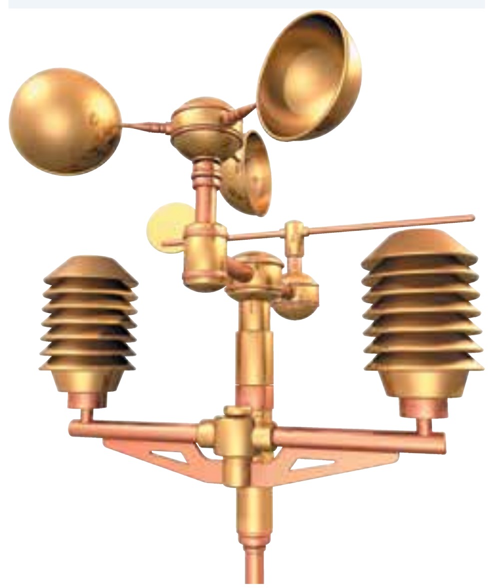
The Earth's climate is always changing. It always has and always will. So why has climate change become the single most important issue for so many people in these early years of the twenty-first century?

The variation of climate over the Earth's surface is largely the result of four major influences.

1. **The amount of energy from the sun reaching the surface**

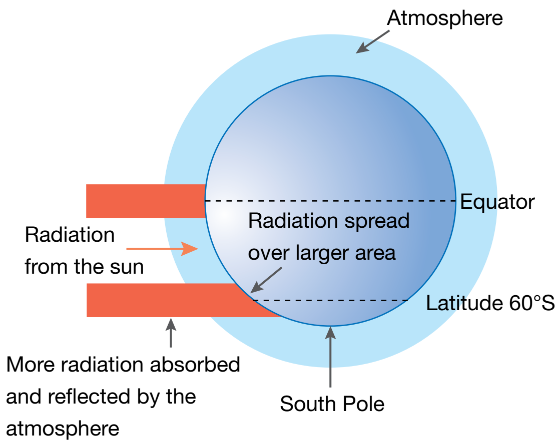
   Because the Earth is almost spherical in shape, the energy from the sun that reaches the Earth's surface is spread over a larger area in the polar regions than near the equator. That is, the amount of energy reaching each square metre of the Earth's surface in the polar regions is less than near the equator. It is the difference in surface temperature between the poles and the tropics that causes the movement of air that we know as wind.

Weather stations contain devices such as a thermometer to measure temperature, a barometer to measure atmospheric pressure, a hygrometer to measure humidity, an anemometer (pictured; this one has cup-shaped turbines) to measure wind speed and a wind vane to measure wind direction.



2. **The differing abilities of land and water to absorb and emit radiant heat**
   During daylight hours the land absorbs **radiant heat** from the sun more quickly than does water. At night heat is radiated from the land more quickly than from the water. As a result, the ocean temperature changes less on a daily basis than air and land temperatures, and coastal climates are protected from the high and low temperature extremes of inland climates.
3. **The tilt of the Earth's axis**
   The tilt of the Earth's axis results in the polar regions receiving little or no solar radiation for six months of each year.
4. **The features of the land**
   The temperature of the part of the atmosphere that contains all of the Earth's landmasses decreases with increased height above sea level. In addition, mountain ranges have a dramatic effect on the climate of nearby regions. They can block the path of the wind blowing towards them, forcing the air to move quickly upwards to form almost permanent clouds, as water vapour in the air condenses quickly. Sandy soils reflect more energy from the sun than dark, fertile soils. Fresh snow reflects up to 90 per cent of the sun's energy that reaches it. Heavily vegetated areas absorb much more of the sun's radiation than bare land because plants use it to photosynthesise.

The spherical shape of the Earth results in less of the sun's energy reaching each square metre of the Earth's surface in the polar regions than near the equator.



14.3.2 Ocean currents

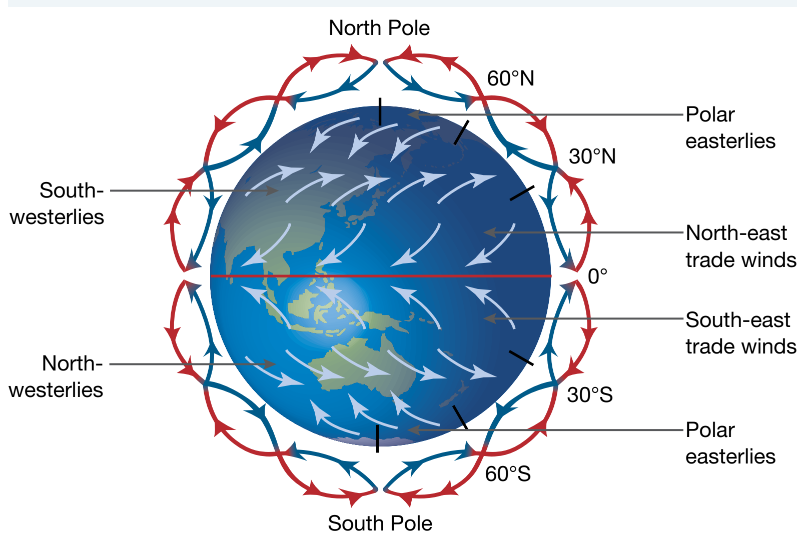
The water in the Earth's oceans is constantly moving in currents. Ocean currents are the result of the temperature difference between the tropics and poles, and the Earth's rotation. Warm surface water near the equator sinks and cools as it moves towards the poles, while the cold water in polar regions rises and warms as it moves towards the equator. Warm and cold ocean currents move huge volumes of water past coastal regions and have a major influence on their climate. The Gulf Stream (at top left in the map on the next page), for example, carries warm water from the equator into the North Atlantic Ocean, keeping Great Britain, Norway and Iceland warmer than other regions at similar latitudes. Cold water currents cool coastal regions that would otherwise be hot.

14.3.3 The influence of wind

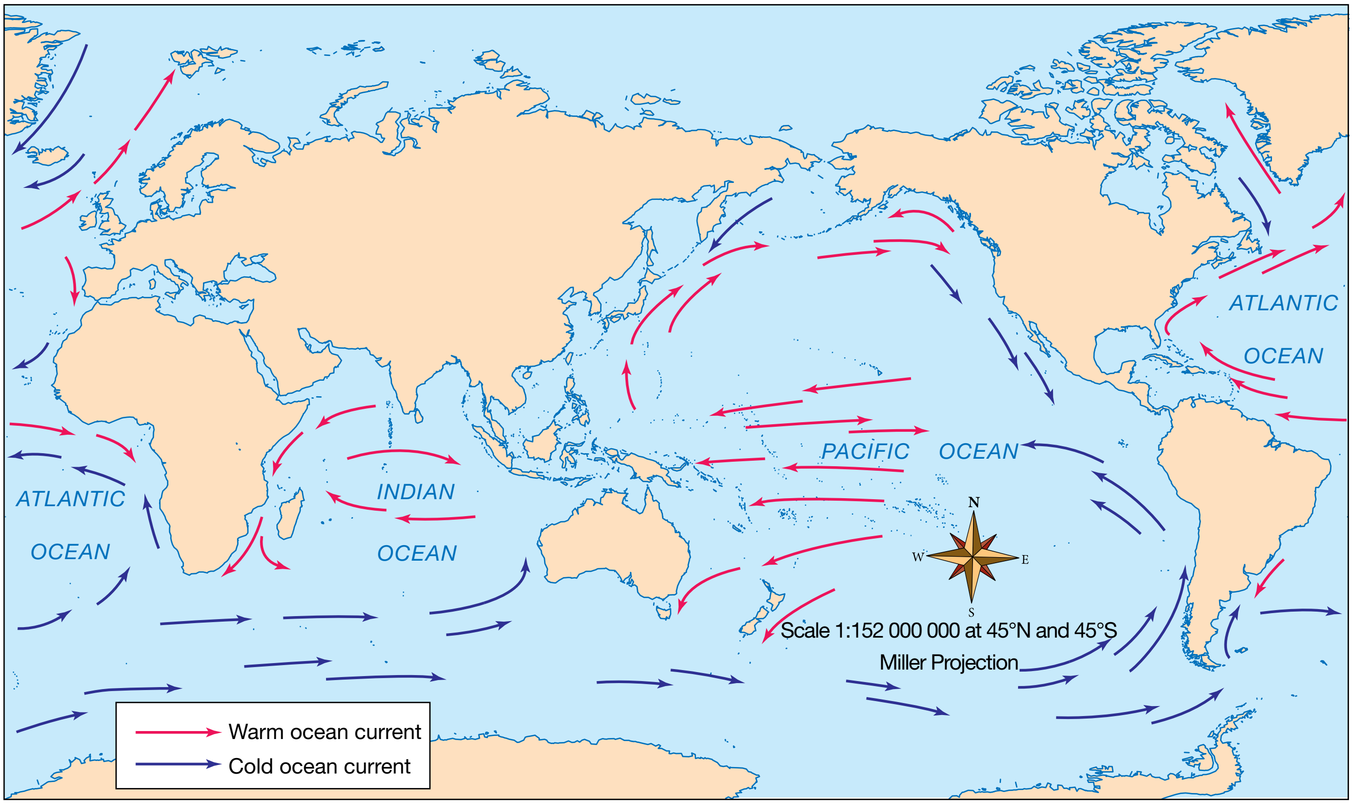
The differences in surface temperature between the poles and the tropics cause the large-scale convection currents that create wind. Cold air near the poles sinks and moves towards the equator, and hot air near the equator rises and moves towards the poles.

The figure at right shows the effects of these convection currents during March and September, when the sun is directly over the equator. The winds shown are called **prevailing winds** and are generally those most frequently observed in each region. The

Convection currents carry warm air towards the poles and cool air towards the equator. Wind patterns are complicated by the rotation of the Earth.



The Earth's ocean currents have a major influence on coastal climates.



direction of prevailing winds is complicated by latitude, the rotation of the Earth about its own axis, the tilt of the Earth's axis and the Earth's orbit around the sun. The actual wind direction at any time depends on numerous other factors including the amount of friction caused by the land surface, ocean currents, local variations in air pressure and temperature, variations in water and land temperature, and altitude.

The wind direction in turn influences air temperatures. For example, during the Australian summer, regions along most of the south coast experience high temperatures when the northerly winds bring in hot and dry air from above the land to the north. The same regions experience cold southerly winds, which bring in cool and damp air from above the oceans to the south.

14.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. List four major factors that influence the variation of climate over the Earth's surface.
2. What causes the large-scale convection currents in the air that create prevailing winds?
3. List five factors that determine the wind direction at any given time or place.
4. **Outline** the causes of warm and cold ocean currents.
5. **Explain** why Great Britain, Norway and Iceland experience warmer climates than other regions at similar latitudes.

Think

6. Why do sandy soils reflect more of the sun's radiation than dark, fertile soils?
7. **Explain** why the average temperature of the Earth's atmosphere was constantly changing for millions of years before humans existed.

8. **Outline** the likely effect on land-based living organisms caused by:
   (a) rising sea levels
   (b) an increase in average temperatures.

Investigate

9. Research, discuss and reflect on each of the following statements about climate change and state your own opinion.
   (a) Australia has vast resources of coal, much of which is exported. The Australian coal industry provides employment and other benefits for the economy. If targets for the reduction of global emissions are high enough to damage the Australian coal industry, the government should not agree to them.
   (b) Developing countries that have little or no industry have not contributed to global warming. These countries should be allowed to increase their carbon dioxide emissions so that they can develop industries and improve their living standards.
10. (a) Carefully examine the table below and suggest what types of vegetation may be found in an environment with a:
   (i) mean annual temperature between 0 °C and 15 °C and a mean annual rainfall around 50–100 cm
   (ii) mean annual temperature between 20 °C and 28 °C and a mean annual rainfall around 250–400 cm
   (iii) mean annual temperature between 20 °C and 28 °C and a mean annual rainfall around 20–30 cm.

Vegetation type	Mean annual temp. (°C)	Mean annual precipitation (cm)
Tundra	−15– −5	0–100
Northern coniferous forests	−5–0	50–150
Mediterranean	−4–17	0–60
Grassland	3–18	50–100
Temperate deciduous forest	3–19	50–300
Desert	−5–30	0–50
Savanna	17–30	50–200
Tropical forests	18–30	100–450

   (b) Find out the mean annual temperature and mean annual rainfall of your local environment. What type of vegetation would you expect to find there? Is this the case? If it is not, suggest possible reasons for the difference.
   (c) Find out what climate change is predicted to occur in your local area due to global warming. Which vegetation would be best suited to this type of environment?

14.4 Global warming

14.4.1 Revisiting the greenhouse effect

Earth's atmosphere acts like a giant invisible blanket that keeps temperatures on our planet's surface within a range that supports life. Within the atmosphere, greenhouse gases trap some of the energy leaving the Earth's surface to help maintain these warm temperatures. The maintenance of Earth's temperatures by these atmospheric gases is called the **greenhouse effect**.

14.4.2 Revisiting global warming

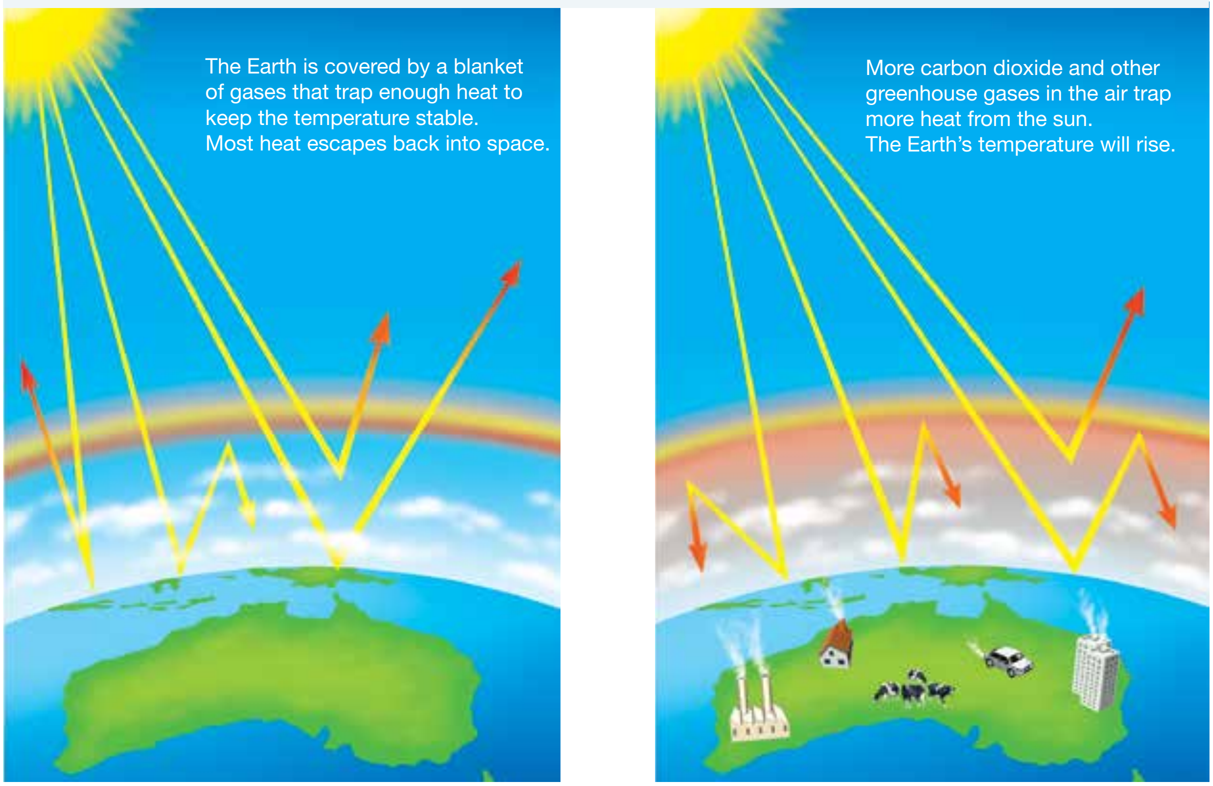
What's the problem?

It's a hot topic. Global temperatures have been increasing and are expected to continue to increase at an accelerated rate. The rising temperature of Earth is known as **global warming**. This may result in the melting of icecaps, rising sea levels, increased coastal flooding, unusual weather patterns and ocean currents, and consequent threats to the survival of some living things.

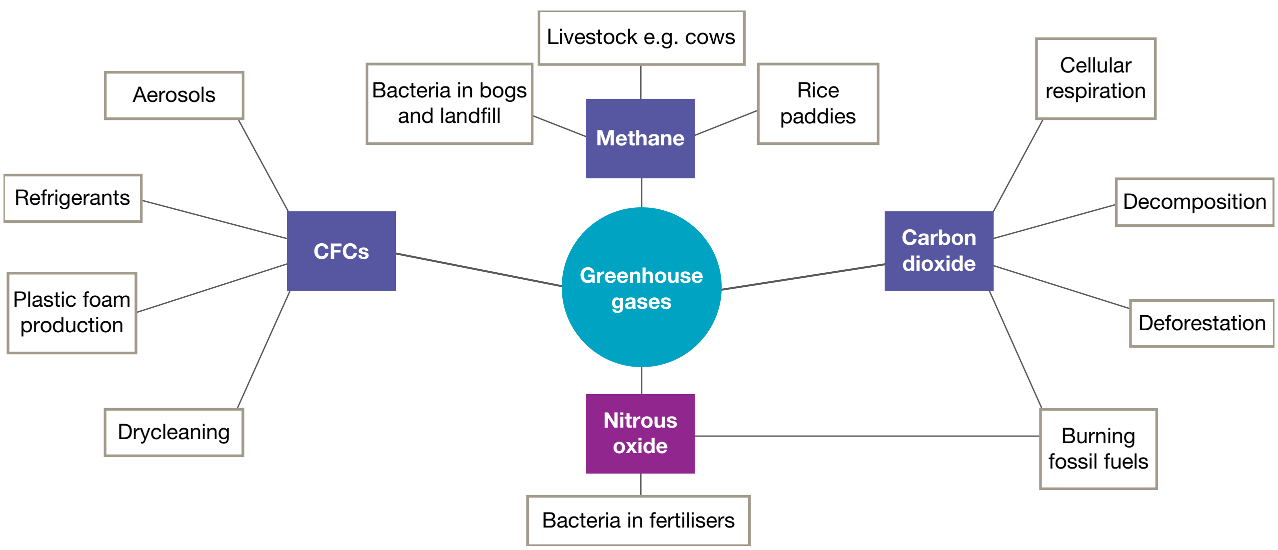
What's the cause?

Some scientists argue that our increased and growing dependence on fossil fuels since the Industrial Revolution of the nineteenth century is a major cause of global warming. They argue that this has resulted in increased levels of **greenhouse gases** (such as nitrous oxide and carbon dioxide) in our atmosphere that are trapping heat, causing the atmosphere to heat up. This is referred to as the **enhanced greenhouse effect**. Some sources of these greenhouse gases are shown in the figure below.

Greenhouse gases and the enhanced greenhouse effect



Some sources of greenhouse gases



Grazing animals such as cattle and sheep produce large amounts of methane as a waste product. Methane is also produced by the action of bacteria that live in **landfills** and soils used for crop production. Much of the nitrous oxide in the atmosphere is produced by the action of bacteria on fertilised soil and the urine of grazing animals.

14.4.3 Connecting the carbon cycle to global warming

Photosynthesis and cellular respiration

Light energy, carbon dioxide and water are used by phototrophic organisms such as plants to make glucose and oxygen. This process is called photosynthesis.

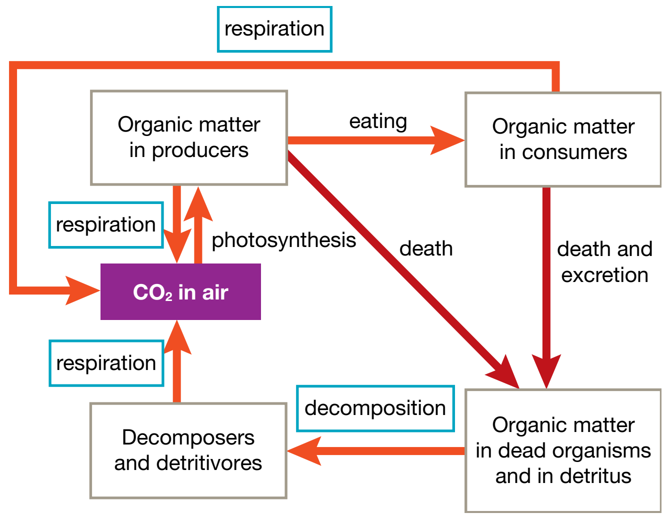
$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{visible light energy}} C_6H_{12}O_6 + 6O_2$$

All living things use cellular respiration. During this process glucose is converted into a form of energy that the cells can use. Carbon dioxide is one of the products of this reaction.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

So, in terms of the carbon cycle, carbon dioxide is taken from the atmosphere during photosynthesis and released back during cellular respiration. This suggests that if producers are reduced in number or removed from the atmosphere, there will be less carbon dioxide removed from the atmosphere, resulting in an overall increase in this gas. This explains why cutting down trees and replacing them with buildings or crops with lower photosynthetic rates can contribute to the enhanced greenhouse effect.

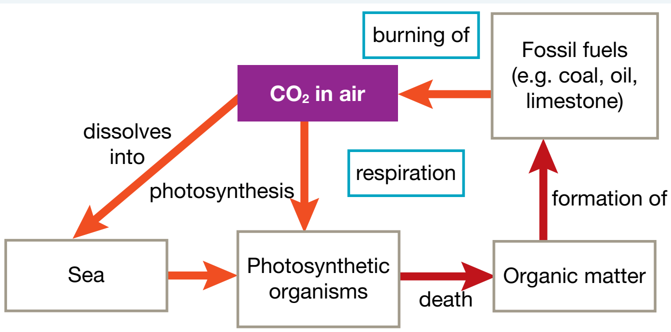
Sources of carbon dioxide within the carbon cycle are circled in blue.



Decomposition and fossil fuels

Carbon dioxide is also released from dead and non-living parts of ecosystems. Some of the carbon dioxide from the atmosphere dissolves into the sea and is absorbed by sea plants and other photosynthetic organisms. These organisms and those that eat them eventually die. Some of their carbon may be used in the formation of fossil fuels. When these fossil fuels are burned, carbon dioxide is released back into the atmosphere.

Carbon dioxide is obtained from a variety of sources (circled in blue) within an ecosystem.



14.4.4 The ozone factor

Ozone (O_3) in the lower atmosphere is also a significant contributor to the enhanced greenhouse effect. Although it occurs naturally, it is also produced by a photochemical reaction that takes place when sunlight falls on emissions from motor vehicles, power stations and bushfires.

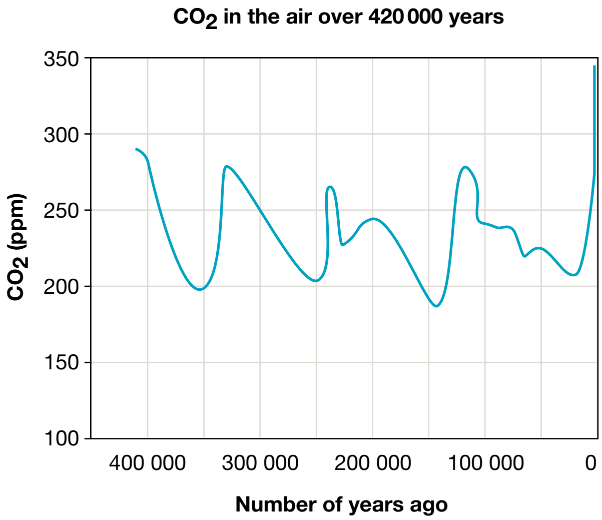
Ozone is produced by photochemical reactions involving emissions from motor vehicles and industry.

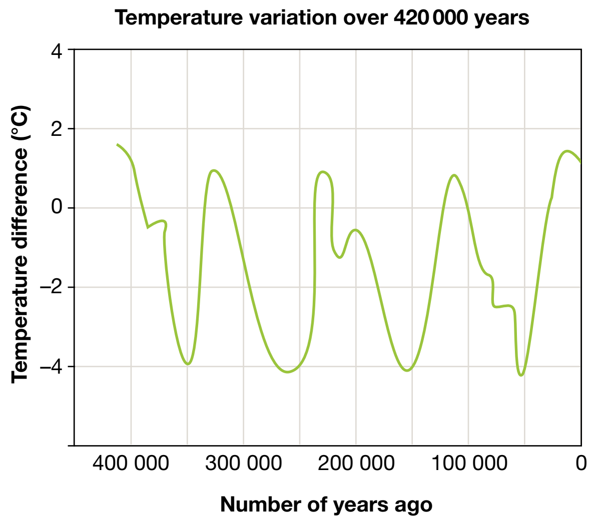
14.4.5 Secrets in the ice

For thousands of years, snow has fallen in Antarctica. The snow turns to ice, which builds up over time. Dust, gases and other substances from the air become trapped in the ice. The trapped substances provide information about what was in the air at the time the snow fell.

Scientists have used **ice cores** to track the air temperature and concentration of carbon dioxide near the Earth's surface. The graphs below show how these have changed over the 420 000 years leading up to the year 2000.

The carbon dioxide concentration is shown in parts per million (ppm) by volume. The temperature difference shown is the deviation from the average temperature now (represented by 0 on the vertical scale). The pattern of changing temperatures resembles the pattern of the change in carbon dioxide concentrations.

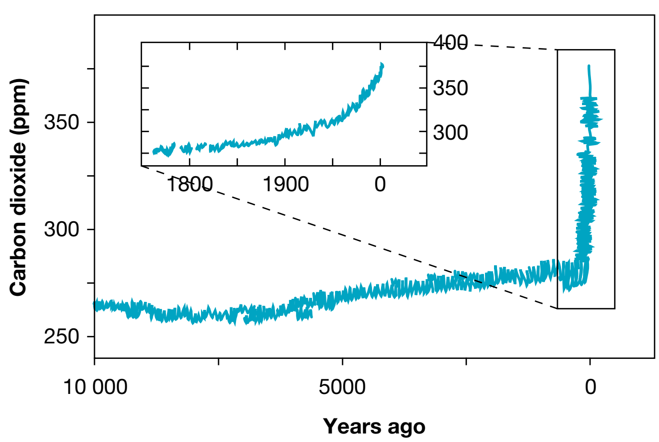




The graph below right shows the dramatic increase in the amount of carbon dioxide in the atmosphere since the Industrial Revolution. During the current decade the concentration of carbon dioxide has risen to approximately 390 parts per million.

This ice core was drilled from more than 3.7 km below the Earth's surface. Parts of it are more than 150 000 years old.

This graph shows the concentration of carbon dioxide in the atmosphere over the past 10 000 years. Note the rapid increase since the beginning of the Industrial Revolution.



14.4.6 Climate models

Meteorologists and other scientists use computer modelling to make predictions about climate change and the possible consequences. The computer programs used to model climate change simulate the circulation of air in the atmosphere and water in the oceans. An immense amount of data collected from the atmosphere, ocean and land surface is used, together with mathematical equations that describe the circulation. The laws of physics and chemistry, including the laws of conservation and energy, along with Newton's Laws of Motion, are an important part of the modelling process.

Global temperature

Although the exact increase in global temperature is not certain, it is generally agreed that during the next hundred years it could increase by between 1 °C and 4 °C. Although that doesn't sound like much, the consequences are very serious. Computer modelling suggests that the global temperature will not increase evenly across the continents. According to CSIRO, in Australia temperatures could increase by up to 2 °C by 2030 and up to 6 °C by 2070. As a consequence there will be more hot days and fewer cold days, an increase in rainfall in the north-east and a decrease in the south, more bushfires, and more destructive tropical cyclones.

Rising sea levels

According to tide-gauge records, the average global sea level has increased by between 10 and 20 cm during the past 100 years. Sea levels are expected to rise further due to:

- the warming ocean water and its resulting thermal expansion
- the melting of glaciers, the polar icecaps and the ice sheets of Greenland and Antarctica. According to NASA, sea ice in the Arctic is melting at the rate of 9 per cent every ten years. Of the world's 88 glaciers, 84 are receding due to melting ice.

Rising sea levels are likely to cause the flooding of low-lying islands and coastal regions.

Frozen soil

Much of the soil on or below the surface of very high mountains in the polar regions is permanently frozen. Known as **permafrost**, this soil is likely to gradually thaw out as global air temperatures increase. There is a massive amount of carbon stored in permafrost and scientists fear that as it thaws, large quantities of carbon dioxide and methane will be released into the atmosphere. This in turn would increase the rate of climate change.

Another problem associated with the thawing of permafrost is the risk of the collapse of buildings, bridges, roads, pipelines and other structures in populated areas of the northern polar regions. The foundations or bases of many of these structures are embedded in permafrost. As it thaws, any ice present melts, making the soil damp and unstable.

The low-lying Pacific nation of Kiribati is planning to relocate its population because of the threat of rising sea levels.

14.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Suggest why Earth's atmosphere has been described as a giant invisible blanket.
2. What is:
   (a) the greenhouse effect
   (b) the enhanced greenhouse effect
   (c) global warming?
3. Suggest four consequences of global warming.
4. Give examples of three types of greenhouse gases and at least two sources for each.
5. **Identify** the links between photosynthesis, cellular respiration, decomposition, fossil fuels and global warming.
6. **Explain** why ozone in the Earth's stratosphere is important to humans and all other life on Earth.
7. **Explain** how scientists are able to determine the air temperature and the amount of carbon dioxide in the atmosphere hundreds of thousands of years ago when such measurements were never recorded.
8. **Explain** how the thawing of permafrost could increase the rate of global warming.
9. **Outline** the actions that individuals can take to slow the rate of global warming.

Think

10. (a) In your own words, **describe** what is meant by the term *enhanced greenhouse effect*.
    (b) Suggest a model or simulation that could communicate this concept to others.
11. Suggest how whales that live on plankton could be affected by global warming.
12. (a) Which of the following actions would you be prepared to take so that you can contribute to the fight against global warming?
    - Walk, cycle or use public transport rather than relying on someone to drive you to school, work or leisure activities.
    - Change your diet so that you eat less meat and more fruit and vegetables.
    - Recycle paper, aluminium and steel cans, glass and plastics.
    - Stop using electric clothes dryers and use outdoor clothes lines in dry weather and indoor folding clothes-airers in wet weather to dry clothes.

    (b) Select one of the actions in part (a) that the government could enforce by passing new laws and explain how it could be done.
13. **Explain** why the average temperature of the Earth's atmosphere was constantly changing for millions of years before humans existed.
14. **Outline** the likely effect on land-based living things caused by:
    (a) rising sea levels
    (b) an increase in average temperatures
    (c) significantly increased rainfall
    (d) significantly decreased rainfall.
15. **Explain** why it is necessary for the Australian government to create legislation to address the problem of global warming.

Investigate

16. In which industrial processes were CFCs used before they were phased out?
17. Use the internet or other sources to find out how carbon capture can be used to reduce the amount of carbon dioxide in the Earth's atmosphere.
18. There are many people who do not believe that climate change and global warming are taking place. There are others who acknowledge that they are taking place but do not believe they are serious problems. Use the internet and other sources to list the arguments that these two groups of people use to support their beliefs.
19. There are new technologies being developed to reduce the amount of carbon dioxide produced per tonne of coal. Research the integrated gasification combined cycle (IGCC).

20. Tetrachloroethene is a solvent commonly used in the dry-cleaning industry in Australia. Not only is this chemical harmful to our health, it can also contribute to photochemical smog. Find out more about this chemical and new technologies, including 'green dry-cleaning', that are being developed, researched or used as alternatives.
21. Research and report on the contribution of two of the following to climate change research.
    - National Climate Change Adaptation Research Facility
    - Australian Terrestrial Ecosystem Research Network
    - Department of Environment and Conservation
    - CSIRO
    - Greenhouse Gas Online
    - Climate Change Research Centre
    - Department of Climate Change and Energy Efficiency
    - Fisheries Research and Development Incorporation
    - Climate Change Research Strategy for Primary Industries.
22. Use the **Global warming** weblink in the Resources tab to find out more about what you can do in your home to reduce the amount of carbon dioxide you produce. Create a brochure to teach people how they can help slow global warming.

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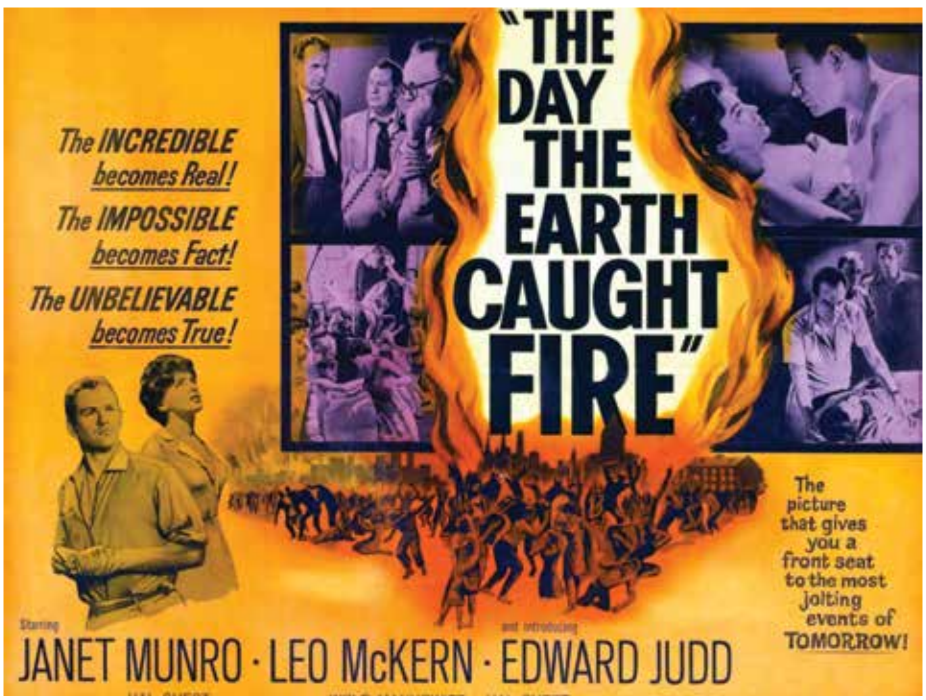
Explore more with this weblink: Global warming

Complete this digital doc: Worksheet 14.3: Ozone layer (doc-12831)

14.5 Heating up for Thermageddon?

14.5.1 Biological implications

Will science fiction become fact? Will some parts of Earth get too hot for humans? Computer models are predicting that this could happen in some parts of the tropics in the future. Some scientists have suggested that, under these hot and humid conditions, even someone standing in the shade in front of a fan could die of heat stress.



Changes in the Earth's climate due to global warming will probably affect the survival of living organisms. The survival of every living thing on Earth is dependent on the characteristics of its habitat, including some that will be affected by climate change. Some living things will be affected more than others.

14.5.2 Will climate change shape human evolution?

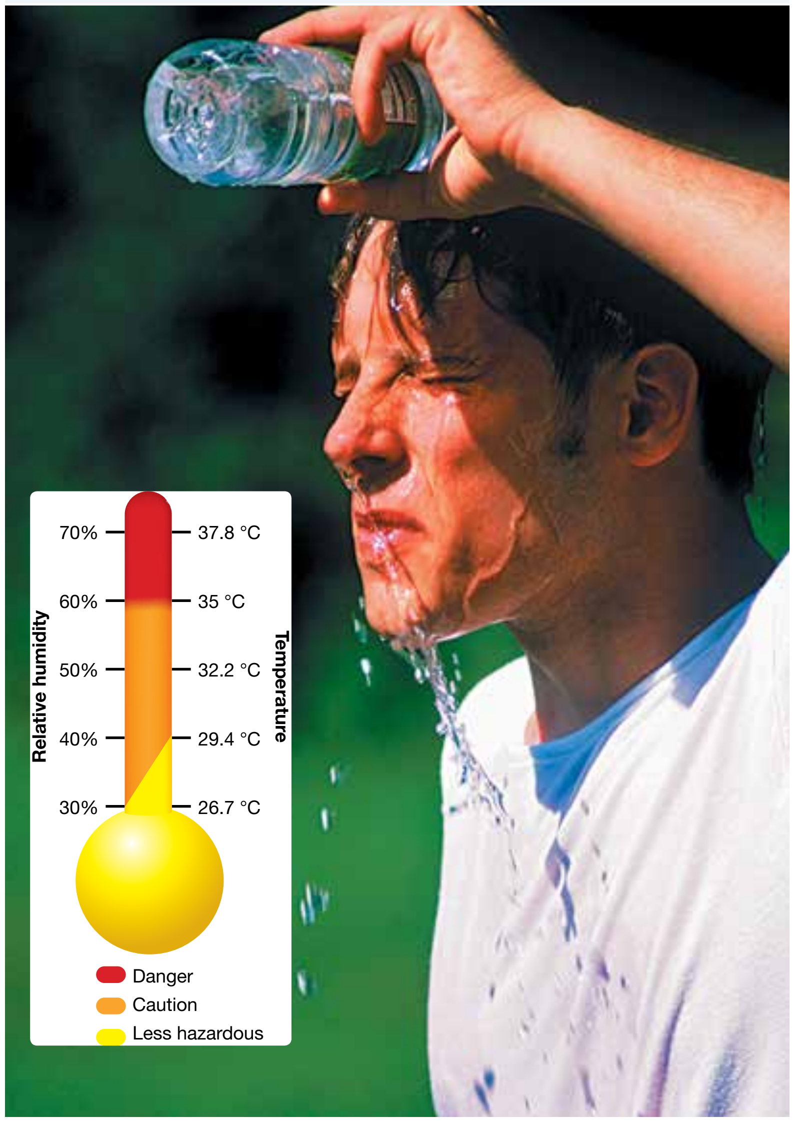
Could Earth get too hot for humans? Is there enough variation within our species so that if things do get too hot to handle at least some of us will survive and our species will continue?

Heat stress threshold

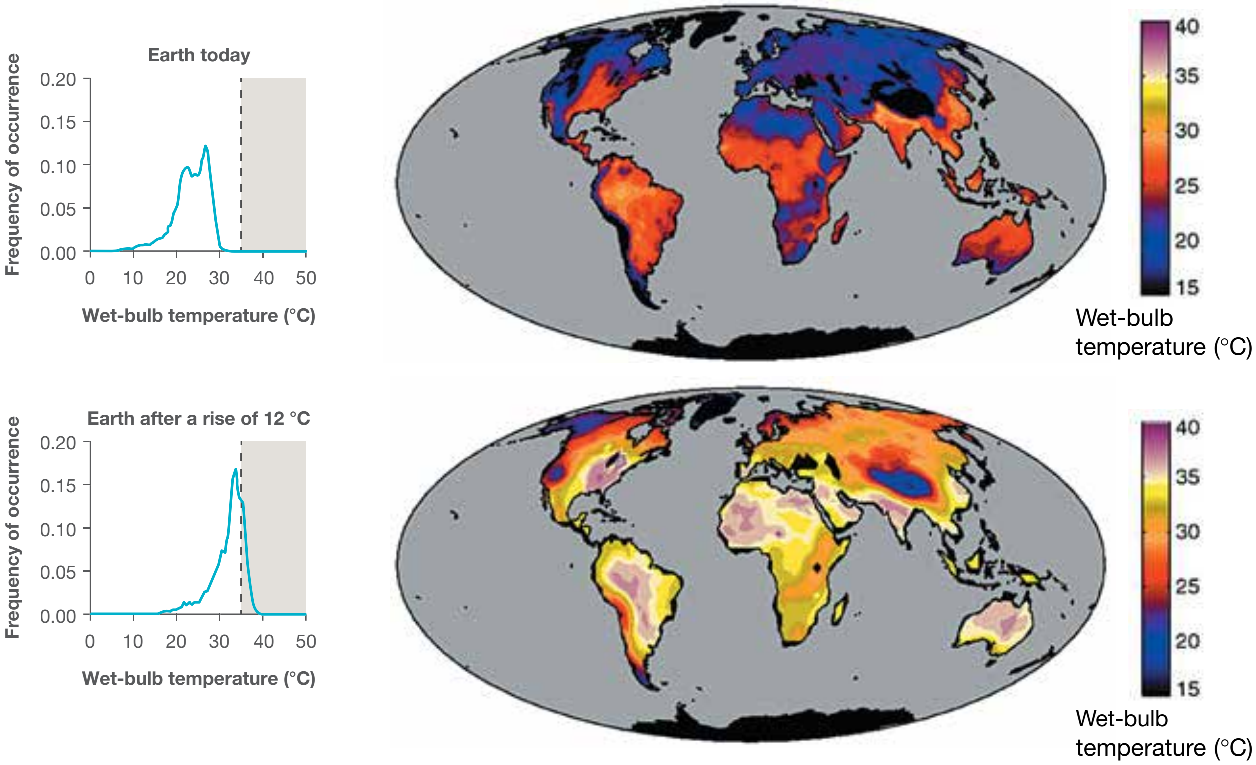
To function normally we need to maintain a core body temperature of around 37 °C. If this core temperature rises above 42 °C, we die. Some researchers have used climate computer models to predict the impact of different levels of global warming on populations. Their data suggests that an increase of around 7 °C in the environment may result in heat and humidity making some places on Earth intolerable, and they predict migrations out of these hot and humid countries will occur. They suggest that at increased temperatures of 12 °C about half of the land inhabited today (including Australia) would be too hot to live in.

Organisms living in the affected areas would need to wear 'cooling suits', live underground or stay in constantly air-conditioned environments. Organisms such as livestock or people who cannot afford these buffers may perish.

Relative humidity not only makes a hot day more unbearable, it can also make it more dangerous.



An increase in heat and humidity due to climate change could render half the world uninhabitable. In regions where the 'wet-bulb' temperature (the temperature to which objects can be cooled by evaporation) exceeds 35 °C (the human heat-stress limit), it would be impossible for people to survive without some kind of cooling system.

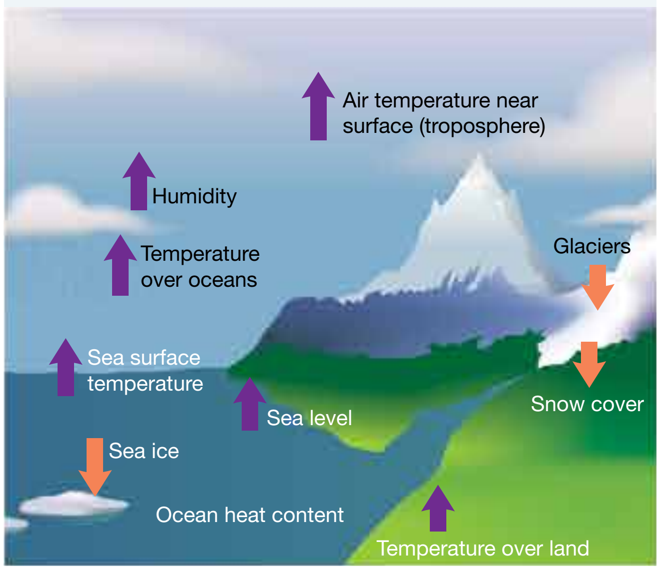


Climate sensitivity

How hot things get will depend on how much more carbon dioxide is pumped into the atmosphere and how much warming it produces. This is known as **climate sensitivity**. The Intergovernmental Panel on Climate Change (IPCC) suggests that temperatures may rise between 1.9 and 4.5 °C (around 3 °C) for every doubling of carbon dioxide pumped into the atmosphere. However, the IPCC's computer model is based only on fast feedback processes and excludes slower processes such as the release of methane from thawing permafrost.

With a climate sensitivity of around 1.9 °C, it may take centuries for our planet to warm by 7 °C. With a climate sensitivity of around 4.5 °C, however, the increase could reach 7 °C within a century if we were to continue with our current levels of carbon dioxide production.

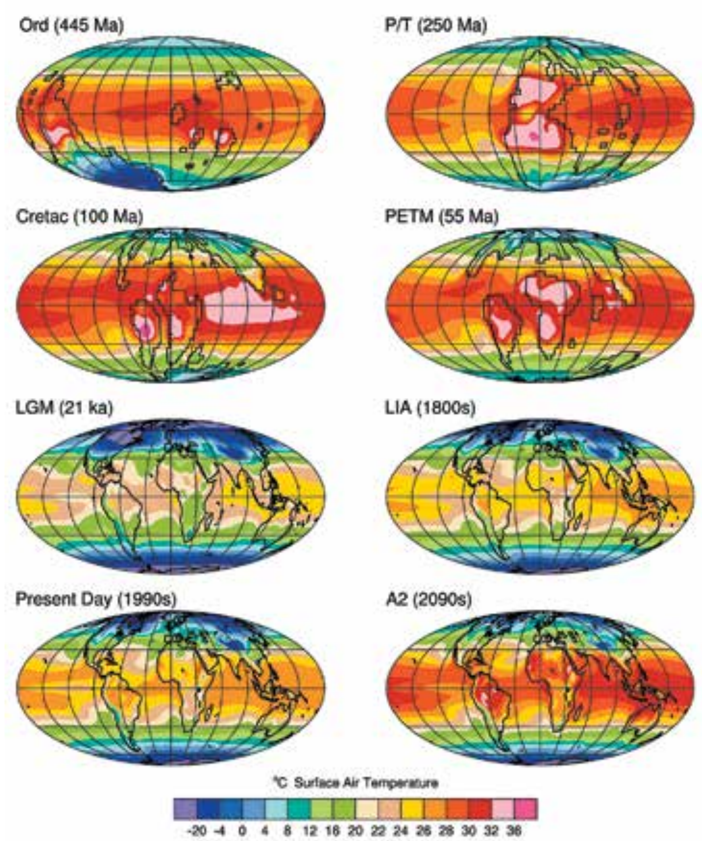
Have you read about any of these indicators or already observed some of them?



Palaeoclimates

Palaeoclimates offer a unique perspective in that they can show the wide range of climates over various time scales, and transitions between them. This information can be used to develop climate models for future climate studies. The figure at right shows examples of various palaeoclimates throughout Earth's history.

Will the study of palaeoclimates throughout history help us develop climate models to predict climates of the future?



HOW ABOUT THAT!

Maplecroft, a British risk-analysis firm, has produced a climate change vulnerability index. Its results suggest that moving to Scandinavia, Ireland or Iceland may be worth the trip. The results are based on more than 40 studies, and focused on a range of risk factors such as the nation's exposure to climate-related disasters, population density, agriculture, and government and infrastructure to cope with climate change. The firm also found that 10 out of the 16 most vulnerable countries were in Asia.

Hot bods?

If Earth keeps warming up, over the long term will we see genetic shifts to select those variations with increased chances of survival? What will a human in a hot future world look like? Some evolutionary biologists have suggested slimmer and taller body shapes that radiate heat better, while at the same time carrying enough fat to be reproductively successful, would be selected for. Some palaeontologists, however, suggest that heat stress would be likely to drive the evolution of smaller mammals.

Disease

With warmer temperatures, global transport and global populations, it is predicted that humans may be more at risk of disease than at any other time in history. There may be an increased incidence of diseases such as food poisoning, skin cancers, eye cataracts and a new range of tropical diseases.

The presence of genes that may provide quick resistance against the onslaught of future diseases is another factor that will determine who survives and who does not.

Are humans still evolving?

A hypothesis has been suggested that global cooling was essential for the large brains of humans to evolve. If this hypothesis is supported, does this mean that global warming may lead to a reduction in the size of the human brain? Other scientists suggest that our modern brains have enabled us to develop culture and that, as long as we have culture and technology, we will have a buffer against hot climates.

Research suggests that the human brain is still evolving. Scientists have identified two genes involved in regulating brain size that have been subject to recent natural selection.

Ocean life

Some marine life will suffer and could even become extinct because of changes in water temperature. Changing temperatures and ocean currents could separate some marine species from their food source. Some marine animals depend on microscopic plankton that float along with the currents. Others depend on species from warmer or colder layers of water than the layer in which they live. It is also possible that some species will suffer from the reduction of oxygen dissolved in ocean water because of increases in temperature. The habitats of some species could be destroyed by rising sea levels.

Biodiversity

Habitats in mangrove swamps, coastal wetlands, coral reefs and other coastal areas may be reduced or lost because of rising sea levels and changed weather patterns. Plants, animals and other organisms adapted to low temperatures and high or low rainfall will have to migrate to other regions. In some cases, where migration is not possible or fails, species could become extinct.

Extinctions due to climate change are likely to add significantly to the loss of biodiversity already caused by loss of habitats due to deforestation and other human activities.

14.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. State what every living thing is dependent on.
2. State the core body temperature that humans need to maintain.
3. Suggest what happens if the core body temperature of a human rises above 42 °C.
4. Suggest strategies that people living in areas affected by extreme heat and humidity use to survive.
5. What is meant by the term *climate sensitivity?*
6. **Outline** what the climate change vulnerability index suggests.
7. **Outline** some possible effects of extreme heat and humidity on:
   (a) humans
   (b) life in the ocean
   (c) biodiversity.

Investigate

8. Find out more about palaeoclimates and related types of research that scientists are currently involved in.
9. While the yields of some types of crops, such as wheat and rice, may increase in conditions where there are higher carbon dioxide concentrations, increases in temperatures may be detrimental to other types of crops. Research and report on the effects of global warming on at least three different types of crops.
10. Research suggests that the human brain is still evolving. Scientists have identified two genes involved in regulating brain size that have been subject to recent natural selection. Research and report on recent relevant studies.
11. A warm period of time from Earth's past was the Palaeocene-Eocene Thermal Maximum (PETM) 56 million years ago. **Investigate** the PETM and report on the types of life forms living at that time and how they coped with warm temperatures.
12. Some palaeontologists suggest that mammals get smaller the warmer the climate. **Investigate** this hypothesis and record your evidence for or against it with current examples.
13. The advice of some scientists is that, as evolution is a slow process, it is unlikely that any adaptation would save us from global warming in time to escape it. They suggest that the answer to surviving climate change is in our skulls. Research and report on the following.
    (a) Did global cooling allow humans to evolve their big brains?
    (b) Can we use an Earth-systems computer to investigate the hypothesis in part (a)?

14. Use the **Thermageddon** weblink in the Resources tab to watch a video discussing the effect of increasing temperature on the human body.
15. Use the **Global warming mind map** weblink in the Resources tab and scroll down to find the mind maps related to global warming. Then create your own mind map on the basis of what you have learned in this topic.

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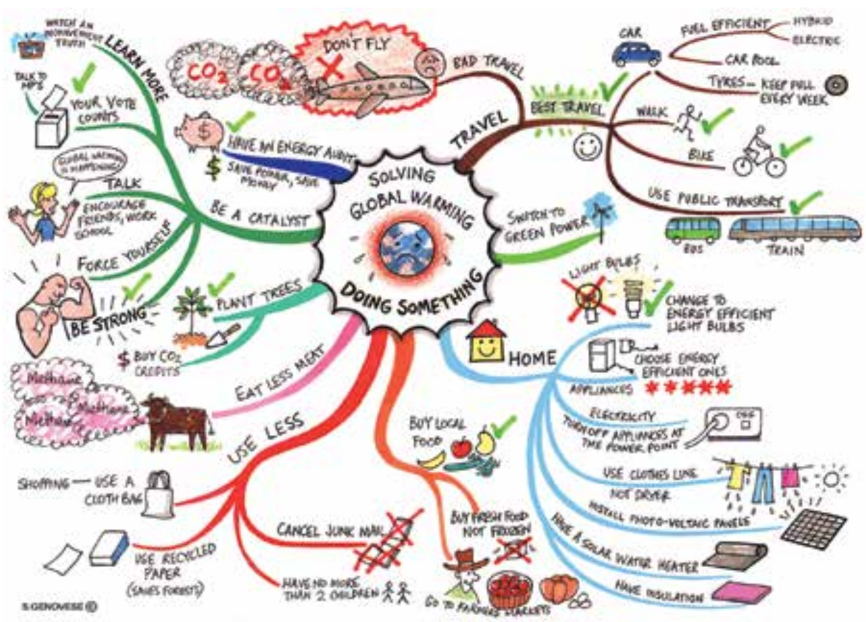
Explore more with this weblink: Thermageddon

Explore more with this weblink: Global warming mind map

14.6 Some cool solutions

14.6.1 Finding solutions



Okay, so there might be a climate change problem. What can we do to fix it?

No-one can be certain about the actual consequences of global warming. There are so many variables that influence climate that computer modelling cannot provide completely accurate predictions. However, there is plenty of evidence to indicate that the levels of the greenhouse gases carbon dioxide, methane and nitrous oxide have been increasing over the past 100 years and will continue to increase.

It is clear that global warming must be slowed by reducing the emission of greenhouse gases. This is no easy task and requires:

- a significant reduction in our use of fossil fuels. Not only does this require a reduction in our use of electricity, natural gas and motor fuels, it also requires an increase in our use of alternative energy sources such as wind, solar and wave energy. It also requires the development of more energy-efficient devices to ensure that less energy is wasted.
- a change in our consumption of food to reduce our dependence on livestock that release methane and nitrous oxide into the atmosphere. We may have to eat less meat and more locally grown fruit and vegetables.

Wind energy is one of several alternative energy sources that do not produce greenhouse gases.

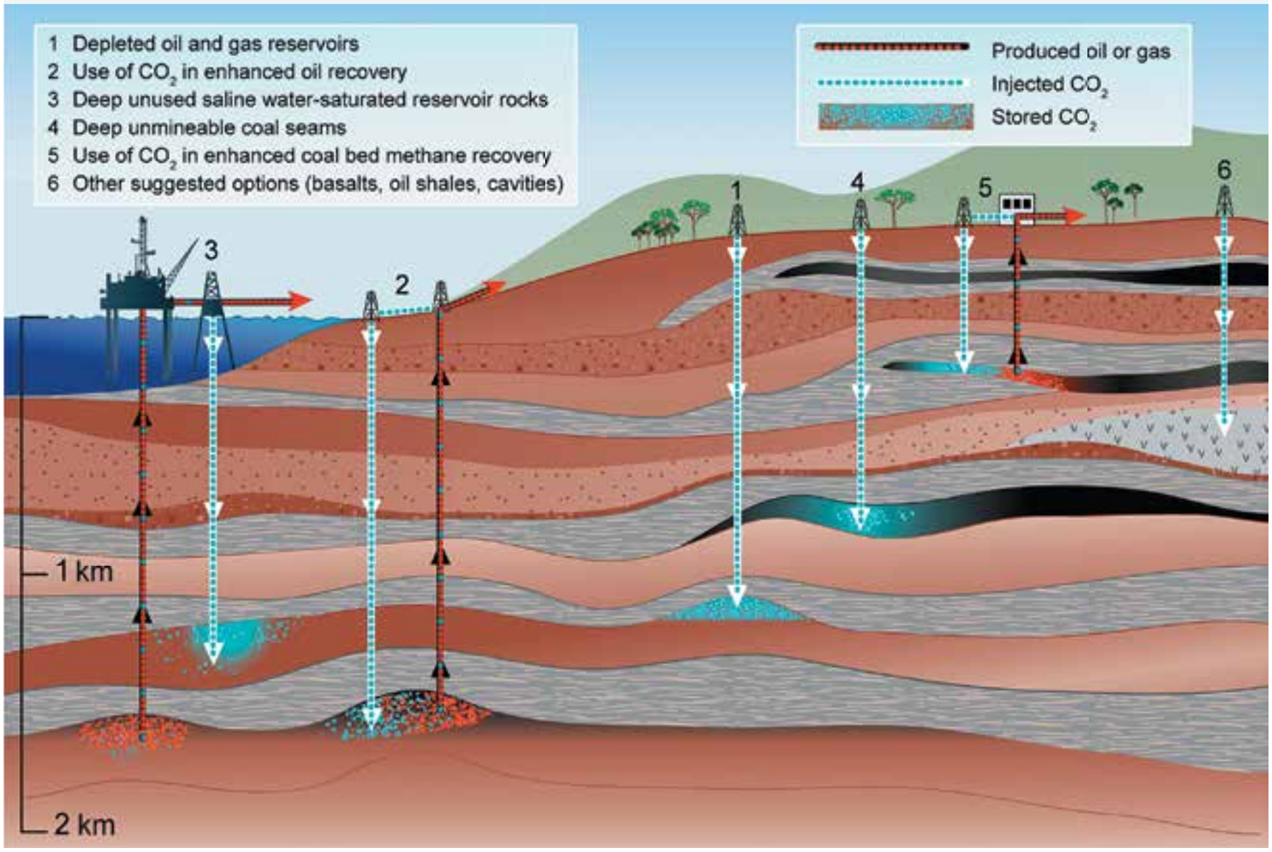
- the recycling of products such as glass, paper, metals and plastic that require the burning of fossil fuels for their production and distribution.

14.6.2 Geosequestration

Geosequestration is a process that involves separating carbon dioxide from other flue gases, compressing it and piping it to a suitable site. There are at least 65 suitable sites (e.g. depleted oil and gas wells) that have been identified in Australia that are capable of taking up to 115 million tonnes of carbon dioxide each year.

Research on this process dates back to the 1970s. Although there are considerable problems with the technology, there is renewed interest in further developing it. It is hoped that it may be used to remove carbon dioxide from the atmosphere and hence reduce its contribution to global warming.

Geological storage options for carbon dioxide



HOW ABOUT THAT!

The word *geosequestration* comes from the Greek term *geo*, meaning 'of the Earth', and the Latin term *sequestrare*, meaning 'to separate'. *Sequestrare* comes from an earlier Latin word meaning 'depositary'.

14.6.3 To chop or not to chop?

We live in a consumer society. The things that we want and need often require large amounts of energy to manufacture and produce and consequently result in the emission of carbon dioxide into the atmosphere. Scientists in forestry and related industries have suggested that one way to reduce carbon dioxide emissions is to produce and use wood products that have been grown under sustainable forest management strategies.

Nick Roberts, Forestry Corporation of NSW chief executive, is passionate about the role that our sustainably harvested native forests can play in combating climate change. The view that wood products produced under this sustainable management have the potential to maintain or increase forest carbon stocks is also supported by the IPCC.

In 2009, Fabiano Ximenes, a forest research scientist, and his colleagues from the NSW Department of Primary Industries (DPI) analysed the carbon content of paper and wood products found in landfill and found that at least 82 per cent of the carbon originally in the sawn timber remained stored in the wood. This research suggested that wood products could act as a carbon 'sink', not only during use, but even after disposal.

Fabio Ximenes, Research Officer — Life Cycle Assessment, DPI

14.6.4 Earth's nine lives

Is it time to think about our relationship with our environment in a new way? The head of the Stockholm Environment Institute in Sweden and his colleagues have identified nine planetary life support systems that provide planetary boundaries that they argue should be adhered to in order to live sustainably. These are:

- rate of biodiversity loss
- climate change
- nitrogen and phosphorus cycles
- stratospheric ozone depletion
- atmospheric aerosol loading
- chemical pollution
- ocean acidification
- fresh-water use
- change in land use.

A sustainable plantation forest of eucalypt trees

14.6.5 Metagenomics

Tammar wallaby

Australian agriculture accounts for about 16 per cent of our national greenhouse emissions. Sixty-seven per cent of this is methane emissions from livestock. CSIRO's Division of Livestock Industries (CLI) is excited about its research that aims to characterise the microbiome (assortment of microbes) in the foregut of Australian marsupials such as the Tammar wallaby (*Macropus eugenii*). One project involves **metagenomics**, a technology that combines DNA sequencing with molecular and computational biology. This technology is being used by the scientists to study methanogens — bacteria that are involved in breaking down plant fibre in the wallaby's gut. While these bacteria produce methane, the levels are a lot lower than those produced by cows and sheep. CSIRO's research may lead to discoveries about why marsupials produce far fewer greenhouse emissions than cows and sheep, and contribute to new biotechnologies that may help us to reduce agricultural greenhouse emissions.

14.6.6 The Kyoto Protocol

In 1997, at a meeting in the city of Kyoto, Japan, most of the world leaders signed a document known as the Kyoto Protocol. The document was a historic agreement to reduce the amount of greenhouse gases produced by industrialised nations. It set targets for reduction of greenhouse gas production up to the year 2012. The targets varied from nation to nation according to a number of factors, including the nation's stage of industrial development. For example, the target for the United States was a reduction of 7 per cent from 1990 levels. For Japan and Canada it was a reduction of 6 per cent. For the Russian Federation and New Zealand it was 0 per cent.

However, a signature on the Kyoto Protocol was only an agreement in principle and was not legally binding. The agreement could not come into force until countries producing more than 55 per cent of the world's greenhouse gases confirmed their commitment by ratifying the agreement, thus formally agreeing to the targets set. This took until February 2005. Australia did not ratify the Kyoto Protocol until 2007. The United States refused to ratify it.

The signing of the Kyoto Protocol marked the beginning of ongoing cooperation between most of the world's nations to reduce carbon dioxide and other greenhouse gas emissions and slow down global warming. In 2012, 37 countries, including Australia, agreed to a second round of binding targets for greenhouse gas reductions by 2020, but only 7 of those countries have ratified their commitments and only 66 countries have accepted the agreement, whereas 144 countries must accept it to have it come into force.

HOW ABOUT THAT!

Do you use a computer often? Have you ever wondered where all the data you can access through the internet is actually kept? The answer is: on a computer server. Many schools have their own server and most students are allocated a certain amount of storage space on it. The problem is that all these servers need to be kept cool to operate correctly. Servers produce heat and keeping them cool requires a lot of electricity. Much of the electricity needed is produced using fossil fuel, so this contributes to global warming. It has been estimated that, worldwide, computer servers contribute as much as the aviation industry to global warming. One solution is to use less energy in data storage and make efficient use of energy in the IT industry.

In 2015, negotiations began for a third commitment period, resulting in the Paris Agreement. The Paris Agreement allows countries to set their own targets and methods to reduce the risk of global warming after 2020.

14.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Suggest why no-one can be certain about the actual consequences of global warming.
2. If we can't be certain about the consequences of global warming, why bother about it?
3. Suggest three things that can be done to reduce the emission of greenhouse gases.
4. What is geosequestration and why bother with it?
5. Suggest how manufacturing and using wooden products that have been produced using sustainable management may help with fighting global warming.
6. List the nine planetary boundaries that promote sustainable lifestyles that have been suggested by the Stockholm Environment Institute in Sweden.
7. What is metagenomics?
8. **Explain** why CSIRO scientists are studying Tammar wallabies in their research related to global warming.
9. What is the Kyoto Protocol and why is it important?

Think

10. **Explain** why it is necessary for the Australian government to create legislation to address the problem of global warming.
11. Use the **Planetary boundaries** weblink in the Resources tab to find out more about Johan Rockstrom's contributions to science, including the concept of planetary boundaries.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Planetary boundaries

14.7 Global warming — believe it or not?

14.7.1 Global warming is a hot topic

As the physicist Niels Bohr reportedly said, 'Prediction is very difficult, especially of the future.'

While most scientists agree that an increase in the amount of carbon dioxide in the atmosphere is the main cause of global warming, they argue about the details of the cause and about the effects of global warming. The key arguments that scientists are involved in investigating and discussing can be divided into three categories:

1. Are humans responsible for global warming?
2. What will the effects of global warming be?
3. What can be done to stop global warming?

14.7.2 Climate science

Climate scientists are trying to find evidence against the hypothesis that global warming is caused mainly by humans dumping greenhouse gases into the atmosphere. That is, they are considering that the hypothesis may be wrong and are trying to assess other ways in which this warming may be occurring. Over the last 40 years, however, no evidence against the hypothesis has been found.

A difficulty for climate scientists is not just about predicting how the climate will change, but also in estimating the level of uncertainty within the prediction.

14.7.3 Climate science and policy

Global warming is a thorny problem. There are also clashes over climate science and policy. While some refer to this as the climate debate, to those deeply immersed in it, it may feel more like an ugly war. It has included frontline battles between science and opinion, politics, media and human psychology. There has been scepticism, outright denial, disrespect and even name-calling!

An Australian newspaper reported that, in one country, scientists trying to present evidence for human involvement in climate change were accused of holding elitist, arrogant views. The media has also reported that even in our own country some leading scientists have felt ignored and excluded from contributing to the development of key climate policies and discussions.

14.7.4 Alternative theories

Alternative theories about climate change have been developed. Climate change sceptics, for example, believe that humans are not to blame for rising global temperatures and that what is being experienced is merely part of a natural cycle.

PREPARING TO ADAPT TO UNAVOIDABLE CLIMATE CHANGE

The terms ‘adaptation’ and ‘mitigation’ are fundamental to the public debate on climate change. Most efforts to address climate change so far have been almost entirely focused on mitigation — taking action to reduce greenhouse gas emissions and to enhance the world’s carbon ‘sinks’.

But the reality is that no matter how successful these mitigation efforts are, all of the Earth’s species and ecosystems are faced with the challenge of adapting to climate change. This is because the flow-on effects of higher levels of greenhouse gases take time to work their way through the Earth’s complex atmospheric land and water systems.

***Ecos,* April–May 2010**

EFFECTIVELY COMMUNICATING CLIMATE CHANGE

The challenge of clearly communicating climate change to a public understandably alarmed about the associated changes to our world is as real in Australia as it is for other countries, says Dr Bruce Mapston, Chief of CSIRO, Marine and Atmospheric Research.

***Ecos,* August–September 2010**

SCIENTISTS WELCOME 130 000-YEAR RECORD FOR CLIMATE STUDY

Australian scientists have welcomed the success of a five-year Greenland ice core drilling project that is expected to reveal a record of more than 130 000 years and provide an insight into future global climate. CSIRO’s Dr David Etheridge and colleague Dr Mauro Rubino joined the drilling project (http://neem.ku.dk/) last year.

***Ecos,* August–September 2010**

SCIENCE, ‘SCEPTICS’ AND SPIN: FRAMING THE CLIMATE CHANGE DEBATE

As the world experiences its hottest year on record, hard on the heels of the world’s warmest decade, calls for urgent action by climate scientists continue to be challenged. Climate change deniers have mobilised into a vocal global movement that has become adept at misinterpreting the science and the media’s appetite for controversy.

Genuine questioning and scepticism is fundamental to the advancement of science. Australian climate scientist Dr Barry Pittock argues that researchers must apply their critical faculties to both sides of an argument. They must also admit uncertainties and accept that despite the existence of uncertainty, risk management may require immediate policy responses.

***Ecos,* August–September 2010**

ALL BETS ARE OFF

Can will make simple predictions about climate change? Climate scientists have ripped up their old forecasts of greenhouse gas emissions in the next century, warning that they could be much too optimistic — or too pessimistic.

***New Scientist,* 18 September 1999**

KEEP CALM AND CARRY ON

Like it or not, the weight of evidence is such that we must conclude the human activity is almost certainly the cause of the recent global warming. It would be perverse to conclude otherwise.

***New Scientist,* 27 February 2010**

CLIMATE CHANGE OR NATURAL VARIABILITY?

Meteorological records since the 1950s reveal a decrease in rainfall that is consistent with anthropogeenic climate change, but a different picture emerges when looking at records since 1900.

***Australian Science,* July/August 2010**

ARCTIC OCEAN'S GAS ATTACK

While the world bickers over the extent and effects of climate change, an expanse of Arctic Ocean seabed is quietly bubbling methane into the air. It's the first time that the ocean has been caught releasing this power greenhouse gas on such a scale. The discovery will rekindle fears that global warming might be on the verge of unlocking billions of tonnes of methane from beneath the oceans, which could trigger runaway climate change. The trouble is, nobody knows if the Arctic emissions are new, or indeed anything to do with global warming.

***New Scientist,* 13 March 2010**

14.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Think

1. In 2010, the IPCC concluded that the increase in the Earth's surface temperature during the second half of the twentieth century needed to be simulated by models that included anthropogenic forcing as well as natural factors. Find out more about anthropogenic forcing and why the IPCC argues that it should be considered in the climate models. Do you agree with the IPCC? **Justify** your response.
2. In 2011, the IPCC estimated that if we continue as we currently are then average global temperatures will rise by 1.8–4.0 °C by 2100 and sea levels will rise an estimated 23–47 cm.
   (a) Research predicted rises in temperature and sea levels. Do you consider the IPCC's estimates to be conservative, exaggerated or in the middle of the two? Justify your response.
   (b) Do you think the IPCC is a credible authority on climate change? Provide reasons for your opinion.
3. It is generally agreed that global warming will lead to worldwide changes in weather patterns, gradual melting of icecaps and rising sea levels. Do you agree with this statement? What is the evidence?

Investigate

4. One of the difficulties of using models to predict future events such as carbon dioxide emissions is that they need to make assumptions about a series of possible future states that are based on known facts, rather than on accurate measurements of events from the past. This factor provides the opportunity for bias in selection. Find out more about the computer models used to predict these events and whether there may be any bias. Share and **discuss** your findings with others.

5. There have been suggestions that the funders of climate research are only supporting studies that set out to prove that global warming is caused by humans. Find out more about the types of climate research being performed and who is funding them. On the basis of your findings, do you agree or disagree with the suggestion? **Justify** your response.
6. Find out what *peer review of research findings* is and **discuss** your findings with others.
7. Find out more about these court cases for and against a greener world.
   - Kivalina vs Exxonmobil
   - Comer vs Murphy Oil
   - Texas vs Environmental Protection Agency (EPA)
   - Connecticut vs American Electric Power (AEP)
8. **Distinguish** between *environmentalist* and *environmental scientist*. Make a list of the types of comments that each may have about global warming or climate change.
9. *Climate change is a natural event and not caused by human activity*.
   (a) Research information related to this statement.
   (b) Using a table like the one shown below, and criteria that you have discussed with others and agreed on, **evaluate** each reference you use for:
   - authority/reputable source
   - bias
   - validity/accuracy.

   (c) Organise your material into a PMI chart or SWOT analysis.
   (d) Organise a class debate on the statement.

Reference title, author, date	Plus	Minus	Interesting	Other comments	Reputable? (0 = not reputable, 3 = very reputable)	Bias? (0 = very biased, 3 = no bias)	Accuracy /validity? (0 = not accurate or valid, 3 = very accurate and valid)
					0 1 2 3	0 1 2 3	0 1 2 3

Discuss

10. There have been suggestions that belief is frequently obscuring fact in regard to the climate change issues.
   (a) **Discuss** with others the difference between *belief* and *fact*.
   (b) Suggest criteria that could be used for each of these terms that would enable them to be identified in articles written about climate change.
   (c) Using your criteria for these terms and internet research, find examples of beliefs and facts in climate change articles.
   (d) Share your examples with others in the class.
   (e) As a class, decide on a specific statement or issue that could be used in a class debate.
   (f) Write a presentation that could be used in a debate on climate change. Include a variety of beliefs and facts in your arguments.
   (g) Conduct a class debate on the topic decided on in part (e). Each member of the class is to have a green and a red card. During the debate, when a belief statement or argument is made students are to hold up a red card, and when a fact statement or argument is made they are to hold up a green card.
   (h) Reflect on your experiences regarding the debate and share your reflection with others.
11. Professor Michael Raupach is an atmospheric scientist who is co-chairman of the Australian Academy of Science's climate change working group. In 2011, he made the comment: 'There is an enormous difference between a scientific proposition, for which truth is decided on the basis of empirical evidence, and a

political proposition, which is adopted or fails depending on the strength of people's convictions. Both of these forms of truth are important in our society, but we're in a lot of trouble if we mix them up — unlike human law, the laws of nature can be read, but not redrafted.'

(a) Find out what each of the following terms mean and give an example that could be used to demonstrate it: scientific proposition, political proposition, empirical evidence, conviction (not in the criminal sense), truth, human law, law of nature, redrafted.
(b) In a group, re-read Raupach's statement and discuss its meaning and how it could be rephrased into the language of a Year 10 student.
(c) Share your rephrased statement with others.
(d) Do you agree with Raupach's statement? Justify your response.

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Complete this digital doc: Worksheet 14.4: Global warming (doc-12832)

14.8 Ozone alert

14.8.1 What's the problem?

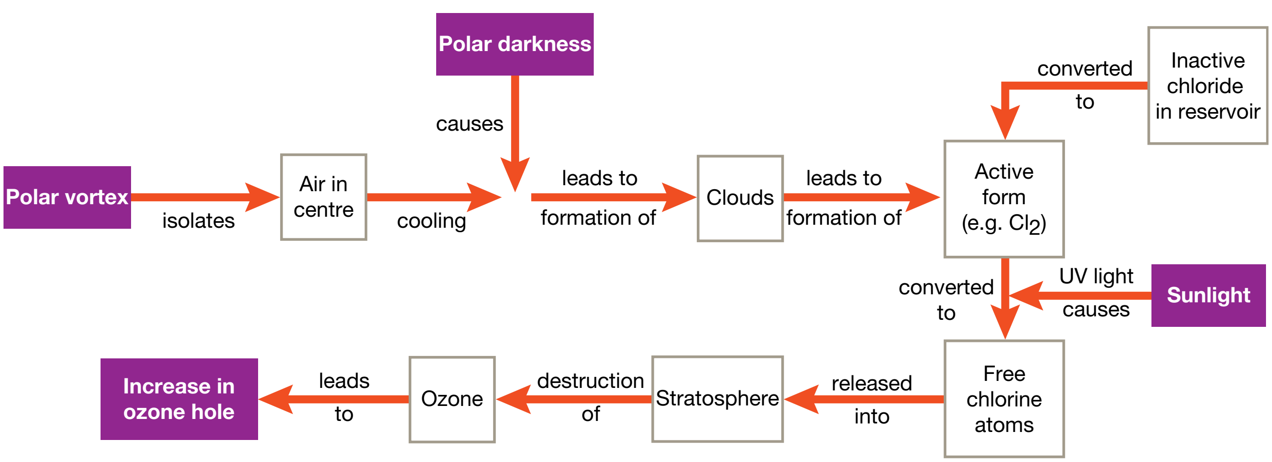
About 90 per cent of the ozone in the atmosphere lies in the stratosphere, which extends from about 10 kilometres to 50 kilometres above the Earth's surface, where it blocks out more than 95 per cent of the ultra-violet (UV) rays entering the atmosphere.

During the 1980s it was discovered that the amount of ozone (O_3) in the upper atmosphere was decreasing rapidly. Any decrease in the amount of ozone in the ozone layer is damaging to all living things as they are adapted to being protected from ultraviolet radiation by ozone. For humans, the damage is in the form of sunburn and skin cancer.

14.8.2 What's the cause?

The main cause of the rapid depletion of ozone in the stratosphere is the emission of chlorine and bromine compounds, particularly chlorofluorocarbons (CFCs), which were once used widely in aerosol spray cans, refrigerators and air conditioners.

Chlorine atoms are involved in reactions that lead to the destruction of ozone.



In the stratosphere, bonds in CFC molecules are broken and free chlorine atoms are released. These chlorine atoms are involved in reactions that destroy ozone. They are then released back into the atmosphere where they continue to be involved in ozone destruction.

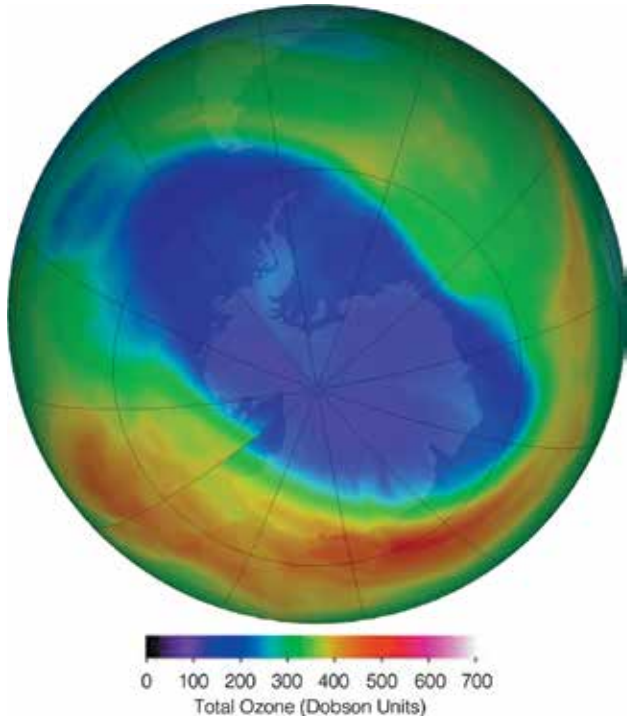
Not long after the discovery of the decrease in ozone, measurements taken by instruments in weather balloons and satellite images showed that the problem was far more serious than initially thought. As a result of international cooperation and recognition that the problem was urgent, the **Montreal Protocol** came into force in 1989.

14.8.3 Ozone friendly

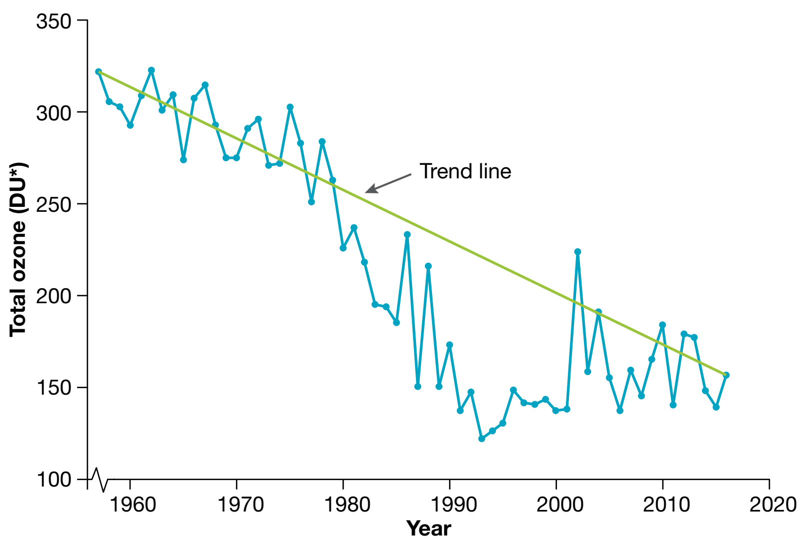
Throughout most of the world CFCs have been phased out and replaced in many cases with hydrochlorofluorocarbons (HCFCs), which deplete ozone to a lesser extent than CFCs but which are also greenhouse gases. These in turn are now being replaced by less harmful chemicals and new technology. The depletion of the ozone layer has already been slowed, and if governments throughout the world continue to honour their agreements to phase out the use of chemicals that threaten the ozone layer, life on Earth will continue to be adequately protected from ultraviolet radiation.

The figure on the next page shows an image from the Total Ozone Mapping Spectrometer (TOMS). This data is based on satellite-based observations that monitor global and regional trends in ozone and other tropospheric aerosols. The Dobson unit (DU) is a measure of total ozone. In the figure the darker reddish colours indicate a higher ozone concentration than the purplish-black colours.

This image shows how large the hole in the ozone layer can be.

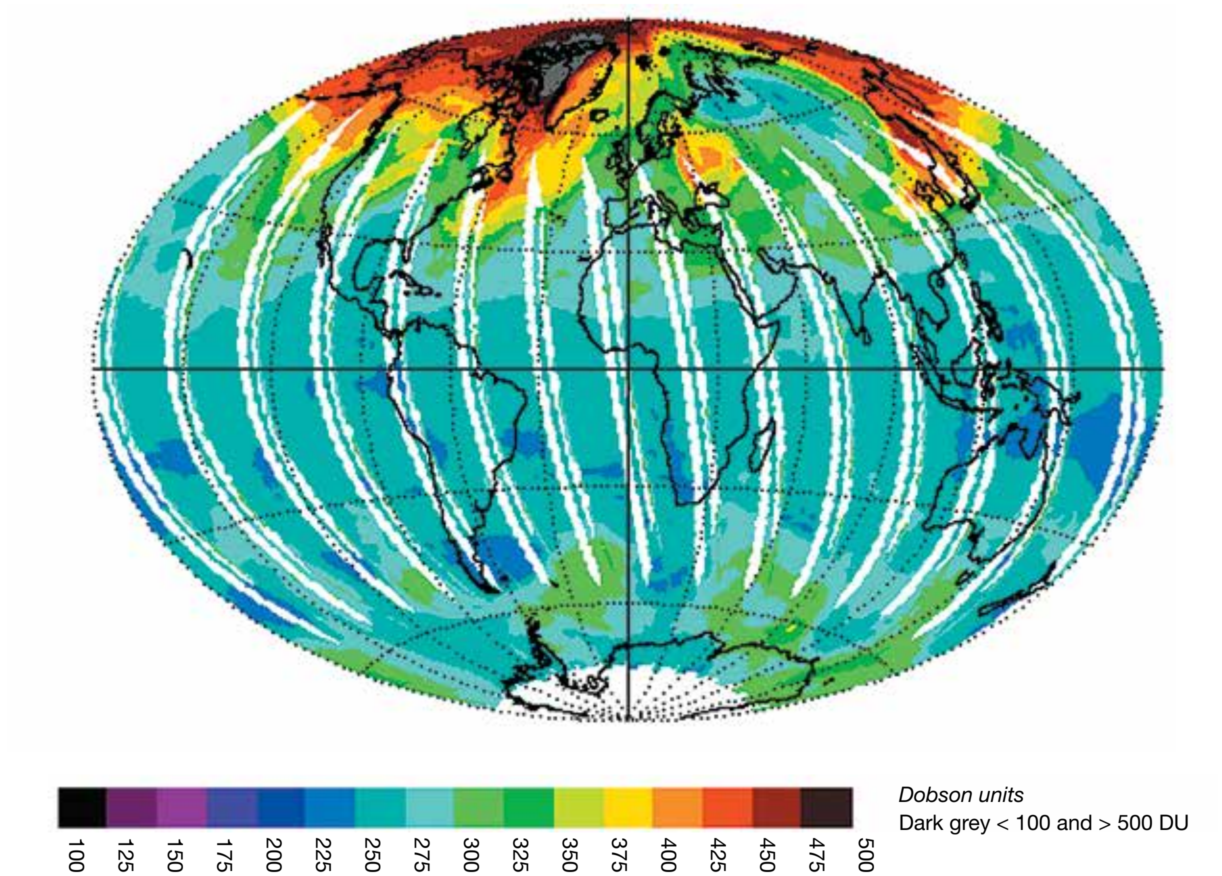


Ozone depletion has reached significant levels since the 1980s. Up to 2003 the ozone loss in spring had grown significantly, but there are now some early signs that ozone levels may be starting to recover.

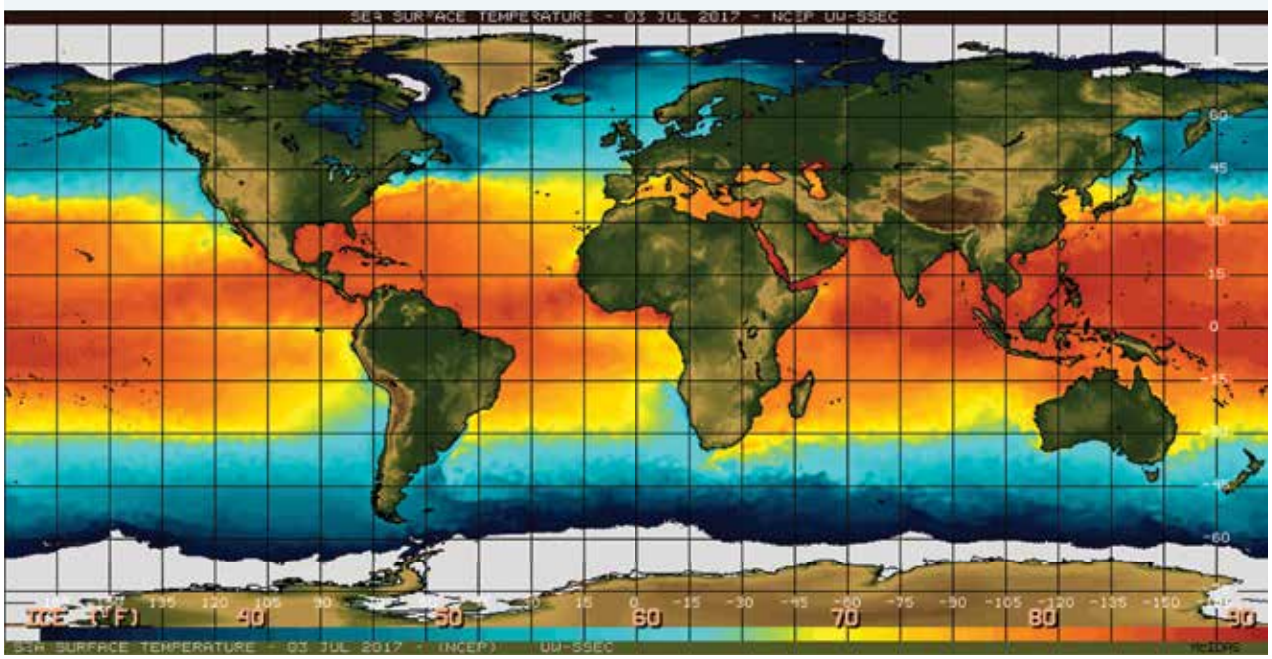


*Dobson units over Halley, Antarctica

Total ozone levels measured on 10 April 2011. Based on satellite observations, the total ozone mapping spectrophotometer (TOMS) provides information on global and regional trends in ozone and other tropospheric aerosols. On the basis of the information shown in this figure, how does Australia rate in terms of its total ozone measurement? Suggest implications of your interpretation of this data.



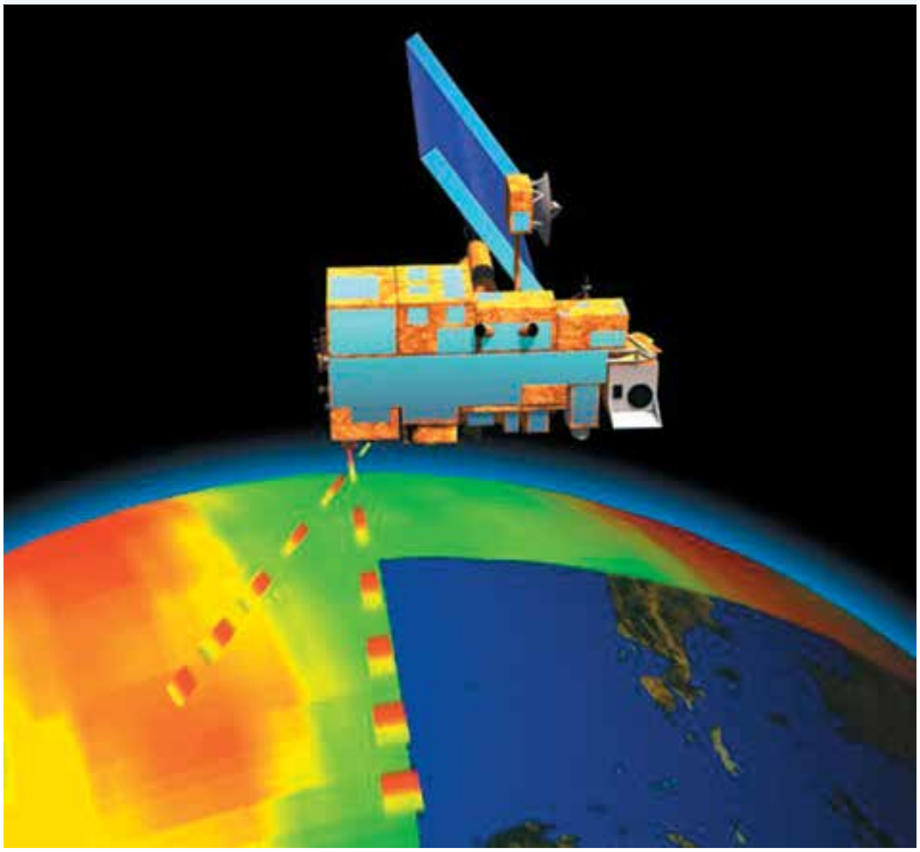
Colour-coded image of the sea surface temperature as revealed by an AVHRR (Advanced Very High Resolution Radiometer) carried on a satellite. Red represents the hottest and purple the coolest sea surface temperature.



14.8.4 Eyes in space

A number of satellites are gathering data on Earth's biosphere from a distance. This type of data collection is called **remote sensing**. The satellite *Terra*, for example, has a number of different instruments that gather different types of data on how Earth is changing in response to both natural changes and those caused by humans. Scientists from different fields are also working together on collaborative projects that use data from remote-sensing observations to improve forecasting systems such as those that warn of future floods.

Terra, the flagship satellite of the Earth Observing System. Specialised instruments carried by *Terra* collect data on the land, oceans and atmosphere of our planet that will provide a record of changes over time.



14.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

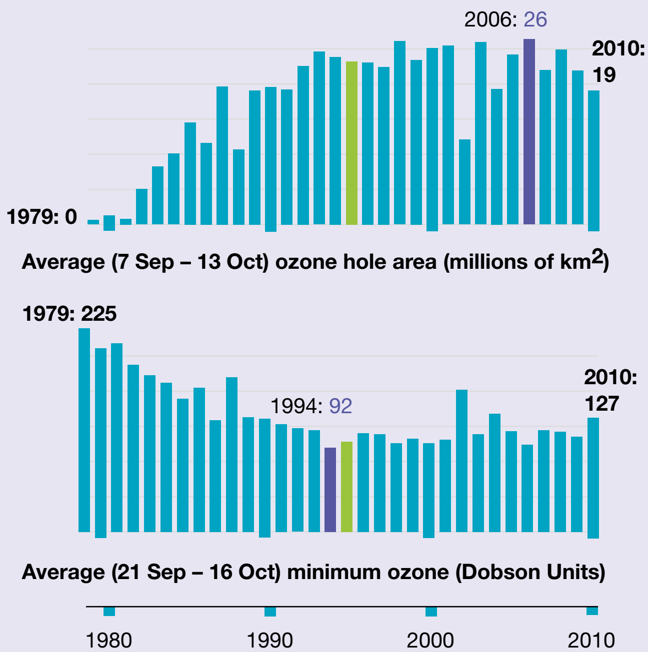
Remember

1. In which part of the biosphere would you find the most ozone?
2. **Outline** why the ozone layer is important to life on Earth.
3. (a) Which types of chemicals are likely to cause a depletion in the ozone layer?
   (b) **Construct** a flow chart to show how these chemicals are involved in ozone destruction.
4. Suggest why the depletion of the ozone layer has been slowed.

Think

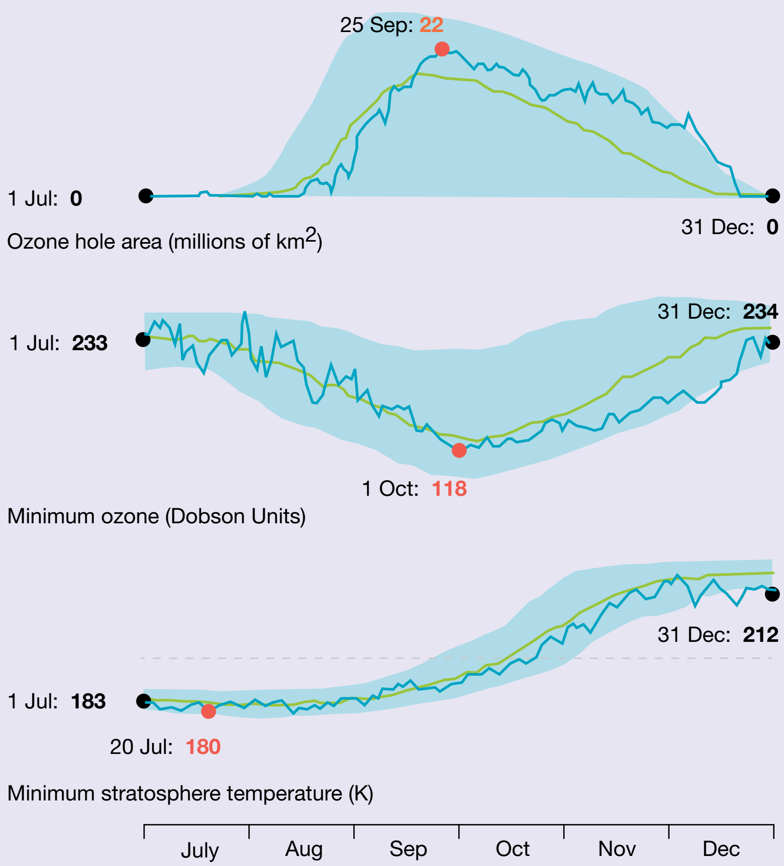
5. (a) What does TOMS stand for?
   (b) How does TOMS get its data?
   (c) What is a Dobson unit?
   (d) Carefully observe the NASA TOMS figure in this subtopic and:
      (i) **describe** patterns of ozone coverage
      (ii) **interpret** the patterns of ozone coverage
      (iii) state the Dobson unit range for Australia
      (iv) **interpret** Australia's ozone pattern in terms of how effectively we may be protected against harmful UV rays.

6. The figure below shows variations in the annual record of the hole in the ozone layer since 1979. In a group, carefully observe any patterns and discuss possible interpretations.



Note: **No data were acquired during the 1995 season.**

7. Use the graphs below to answer the questions that follow.

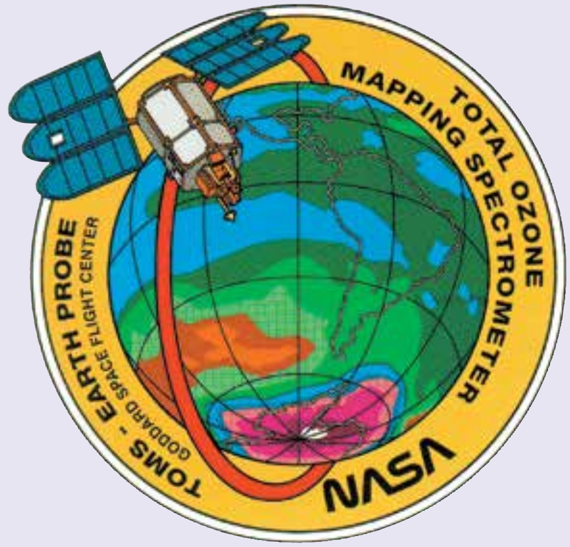


(a) **Describe** the patterns observed in the graphs.
(b) **Interpret** the information in the graphs.
(c) In which part of the biosphere is the ozone layer located?
(d) **Explain** why there is concern about the thinning of the ozone layer.
(e) List examples of three sources of CFCs.
(f) **Outline** how CFCs contribute to the development of the ozone hole.
(g) **Explain** why temperature and the amount of sunlight influences the depth and size of the ozone hole.

Investigate

8. Use the **Sustainable Cities Index** weblink in the Resources tab to view the index developed by the Australian Conservation Foundation (ACF). This index is based on a range of environmental, social and economic issues. It provides a snapshot of the performance of 20 of our largest cities and ranks them from most sustainable to least sustainable.
   (a) Select the city closest to where you live. How did it rate in this index? Do you agree with the ACF's findings? Justify your response. Suggest ways in which your city's score could be increased.
   (b) Select one of the criteria used and find out more about the method used to collect the data.
   (c) Which of the 20 Australian cities scored as being our most sustainable city? For which criterion did it score the highest? Suggest reasons for its high score.
   (d) Which city scored the lowest? Suggest reasons for its low score and what it could do to increase its score if the survey were to be conducted again in the future.
9. Various satellites and data collection instruments are used to measure changes in our environment. Research and report on at least two of the following from each group.
   (a) OMI, TOMS, GOME, NOAA SBUV/2, MLS, Balloon Sondes
   (b) MODIS, MISR, MOPITT, CERES, ASTES

Various satellites collect data to measure changes in our environment.



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Explore more with this weblink: Sustainable Cities Index

14.9 Biodiversity and climate change

14.9.1 Natural climate change

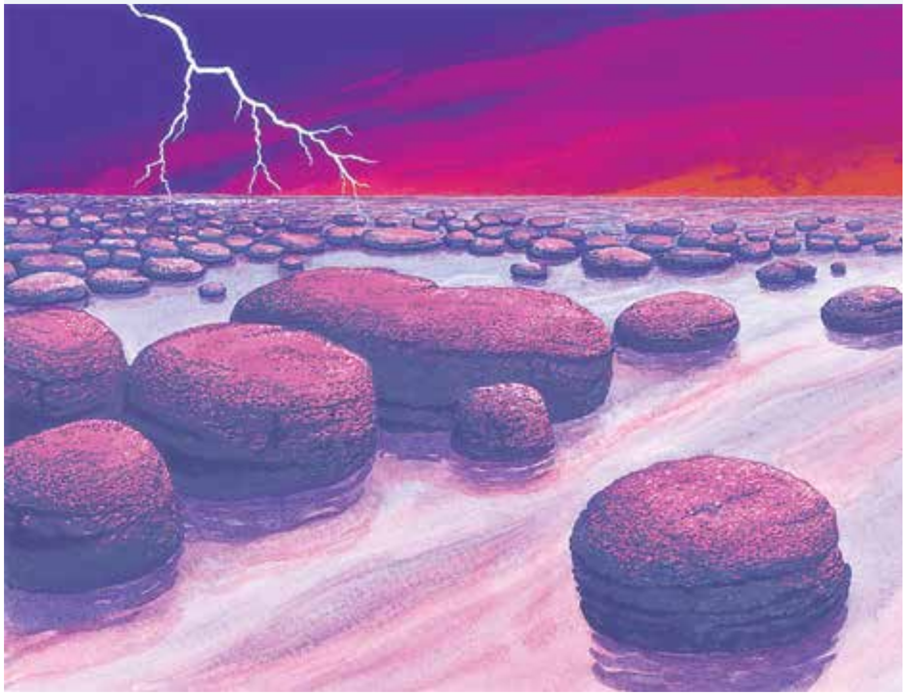
When the first traces of life appeared on Earth about 3500 million years ago, the climate was hostile. Lightning bolts blasted through a warm atmosphere of hydrogen, methane, ammonia, water vapour and carbon dioxide. There was no oxygen until the first living organisms produced it through photosynthesis. Since then, the composition of gases in the Earth's atmosphere and its temperature have been constantly changing.

14.9.2 Biodiversity

The evolution of life forms on Earth has occurred because some organisms are better suited to a particular environment than others. For some to be better suited than others, there needs to be variation or diversity.

In a global sense, **biodiversity** refers to the total variety of living things on Earth, their genes and the ecosystems in which they live. Biodiversity (or biological diversity) exists at the gene, species and ecosystem level.

Earth was a hostile place 3500 million years ago. Fossils provide evidence of structures called stromatolites. They existed in warm sea water and consisted of cyanobacteria, one of the earliest forms of life.



14.9.3 Genetic diversity

Genetic diversity can be considered in terms of variation within the genes (alleles), which are made up of DNA. Genetic variation is important for the long-term survival of a species as it increases the chance that at least one of the variations may enable some of the population to survive to reproduce the next generation.

Diversity in DNA

Each individual contains their own combination of genetic material in the form of DNA. This information is organised into coding and non-coding regions. The coding regions, called genes, contain genetic information for the synthesis of proteins that contribute to the expression of particular features or traits.

Diversity in alleles

Individuals within a species share the same genes that code (with an environmental influence) for a particular feature or characteristic. What differs, however, is that there can be alternative forms of these genes within the individuals. Alternative forms of genes are called alleles. For example, an individual within a species may have a gene for beak shape. The alleles for beak shape may code for hooked or straight shape. So, some individuals may contain the alleles for hook-shaped beaks, some the alleles for straight-shaped beaks and others the alleles for each type.

The particular combination of alleles for a particular trait (or **phenotype**) within an individual is called the **genotype**. For example, if the allele for the hooked beaks is given the symbol *H* and the allele for the straight beaks is given the symbol *h*, then an individual could have a genotype of *HH* or *Hh* or *hh*.

14.9.4 Species diversity

Species diversity can be considered in terms of diversity in populations. While the combination of alleles for a trait within an individual is called a genotype, the combination of all of the alleles within a group of individuals of the same species living in a particular place at a particular time (population) is called a **gene pool**.

All environments change over time. It is the diversity (or variation) of the alleles within this gene pool that contributes to the number of possible combinations that could be used to produce the next generation. Increased variety in the expression of these alleles as phenotypes (traits) of the offspring means an increased chance that some of these offspring will be able to survive in the environment in which they are born and will live — even if that environment changes.

If there is little variation in the gene pool, there is less chance of the offspring being able to survive possible changes in their environment such as those related to climate and the availability of habitat, food, mates or other resources. The consequences of this limited diversity within the population may lead to the **extinction** of the species.

14.9.5 Ecological diversity

Ecological diversity can be considered in terms of the diversity in ecosystems. The extinction of a particular species within an ecosystem may have an impact on the survival of other members within that ecosystem. The species may have been within the same food web and so its disappearance will have consequences for the food supplies of others within this food web. Unless there are other species that can take its place without having a negative effect on others, the survival of other species may be threatened.

Biodiversity within ecosystems could be viewed in terms of the diversity of species within the ecosystem. Increased biodiversity within ecosystems can reduce the consequences of losing a species to which the survival of others is linked. Likewise, reduced biodiversity in these populations can lead to the extinction of other species.

14.9.6 Australia's biodiversity

Biodiversity within Australian ecosystems is influenced by both biotic factors and abiotic factors. Abiotic factors including those that contribute to climate, such as temperature and annual rainfall, can affect the abundance, distribution and types of species within a particular ecosystem. Organisms have particular tolerance ranges for abiotic factors. They cannot survive outside these tolerance ranges.

If global warming results in the development of climatic conditions that are outside a species' tolerance range, and if they are unable to migrate or if the species is unable to adapt to the new conditions, then there is a threat that the species may become extinct. Species that are most at risk are those that have low genetic variability, long life cycles and low fertility, a narrow range of physiological tolerance and geographic range, and specialist resource requirements.

Global warming and Australia's biodiversity

Changes in Australia's biodiversity that may be due to climate change include changes in species ranges and migration patterns, shifts in genetic composition of some species that have a short life cycle, and changes in lifestyle and reproduction rates.

Many plants and their pollinators have **coevolved**. Studies have suggested that climate change has upset the life cycles of pollinators (such as bees). Other studies suggest that climate change is causing the flowering times of some plants to be out of synchronisation with their pollinators. With fewer plants being pollinated, fewer are bearing fruit containing seeds essential to produce the next generation of plants.

Preparing to adapt to unavoidable climate change

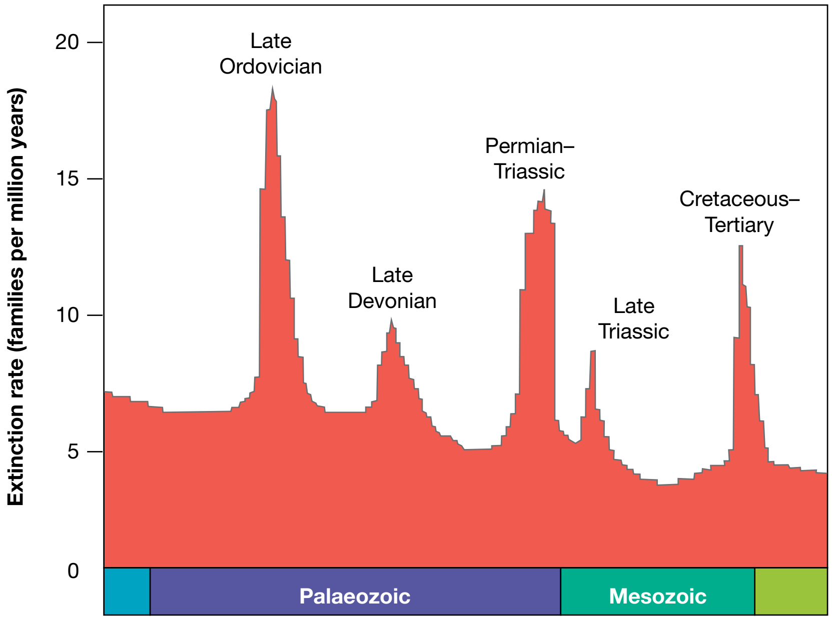
The National Climate Change Adaptation Research Facility (NCCARF) has identified eight priority areas for adaptation research. These are terrestrial biodiversity, primary industries, water resources and freshwater biodiversity, marine biodiversity and resources, human health, cities and infrastructure, emergency management, and social and economic issues.

14.9.7 Mass extinctions

Many scientists believe that we are currently experiencing the sixth mass extinction. Five other mass extinctions have occurred as a result of global climate change. Some argue that humans are responsible for the current mass extinction. The International Union for Conservation of Nature has reported that species are dying out 1000 to 10 000 times faster than they would without human intervention.

Those with the view that humans are to blame divide this sixth extinction into two phases. The first phase began about 100 000 years ago when the first modern humans began to spread throughout the world. The second phase began when humans started to use agriculture around 10 000 years ago.

There have been five mass extinctions in the past – are we currently experiencing a sixth and, if so, is it caused by humans?



CLIMATE CHANGE HITS SE AUSTRALIAN FISH SPECIES

Significant changes in distribution of about 30 per cent of coast fish species in south-east Australia are being blamed on climate change . . . Scientists from the CSIRO Climate Adaptation and Wealth from Oceans Flagships have identified shifts in 43 species.

***Ecos*, October–November 2010**

ULTRAVIOLET LIGHT EXPOSURE DAMAGES TADPOLES

Depletion of the ozone layer has been revived as an explanation for the extinction of amphibians after the discovery that increased ultraviolet-B radiation makes striped marsh frog tadpoles more vulnerable to predators.

Since 1980 more than 150 species of amphibians have become extinct. This compares poorly with background extinctions of 1 every 250 years. 'With amphibians being the most threatened of all vertebrates, and also important indicators of environmental health, understanding the causes of their declines is critical for their conservation, and possibly the conservation of other species,' says Lesley Alton, a PhD Student at the University of Queensland's School of Biological Sciences.

***Australasian Science,* April 2011**

14.9 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. There was no oxygen in Earth's early atmosphere, but there is now. Where did it come from?
2. Suggest a connection between the concepts of *diversity* and *better suited*.
3. **Define** the following terms.
   (a) Biodiversity
   (b) Genetic diversity
   (c) Species diversity
   (d) Ecosystem diversity
4. State the three levels at which biodiversity can exist.
5. **Outline** the importance of genetic variation to the survival of a species.
6. State the form in which genetic material exists in all species.
7. **Describe** the function of genes.
8. **Describe** the relationship between DNA, genes, proteins and traits using a flow diagram.
9. **Distinguish** between the following terms.
   (a) Genes and alleles
   (b) Genotype and phenotype
   (c) Genotype and gene pool
   (d) Survival and extinction
10. **Compare** the survival chances of a species showing low diversity and a species showing high diversity.
11. Suggest the consequences of limited diversity in a population.
12. Suggest how diversity within an ecosystem may increase the survival of species within it.
13. State examples of abiotic factors that can affect the survival of an organism.
14. Suggest a definition for the term *tolerance range* and suggest an example.
15. Suggest a connection between global warming and changed abiotic factors within ecosystems.
16. State the features of species that would be most at risk of extinction in changing climatic conditions such as global warming.
17. Suggest changes in Australia's biodiversity that may be due to climate change.
18. Suggest a connection between reduced pollination of some types of plants and climate change.
19. List the eight priority areas identified by NCCARF for adaptation research.
20. **Outline** the two phases of human contribution to the sixth mass extinction.

Think

21. Are you concerned about the arrival of the Earth's sixth mass extinction? One survey asked people to respond to this question by choosing 'Yes', 'No' or 'Sort of but I won't see the effects in my lifetime'. How would you have responded? **Justify** your response.
22. Do living organisms always have a negative effect on their environment? **Justify** your response and include a supporting example.
23. **Identify** sources of variation for (a) asexually reproducing and (b) sexually reproducing organisms.
24. Suggest ways in which organisms could be better suited to survive in a particular enviroment than others.

Investigate

25. Research and report on coevolution and the possible effect that global warming may have on organisms that are linked by this type of evolution.
26. Research and report on examples of life forms that are able to survive in an oxygen-free environment, both throughout Earth's history and today.
27. Select and research the topic of one of the article extracts in this subtopic.
28. (a) Find out more about:
    (i) coevolution
    (ii) pollination
    (iii) flowering plant life cycles
    (iv) bee life cycles
    (v) extinction
    (vi) climate change
    (vii) pollinator decline.
    (b) Link the terms in part (a) using a mind map or fishbone diagram.
    (c) Research possible implications of pollinator decline for:
    (i) farming and food supplies
    (ii) plant biodiversity on Earth
    (iii) humans.
29. Research and report on the role that museums play in the identification and preservation of species and how this contributes to Australia's biodiversity.
30. The biggest problem connected to the effects of climate in Kakadu's coastal floodplain is the rise in sea level. Salt water has already been intruding in various parts of the park and has affected the local populations of *Melaleuca* (paperbark) trees and magpie geese. Research and report on the current and possible effects of rising sea levels in Kakadu.
31. Research and report on two of Australia's top 15 national biodiversity hotspots using information from the **National biodiversity** weblink in the Resources tab.

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Try out this interactivity: Threats to Earth (int-0218)

Explore more with this weblink: National biodiversity

14.10 Biosphere 2

Science as a human endeavour

14.10.1 Biospherics

Humans living in biospheric systems such as small spacecraft and submarines have used physical and chemical techniques to recycle clean air and fresh water and remove accumulating wastes. As biospheric systems increase in size, however, the basic concepts of cycling of elements and the importance of biodiversity have direct implications on a number of different issues. These include global warming, the protection of endangered species, sufficient food supplies, effective waste removal and clean water requirements.

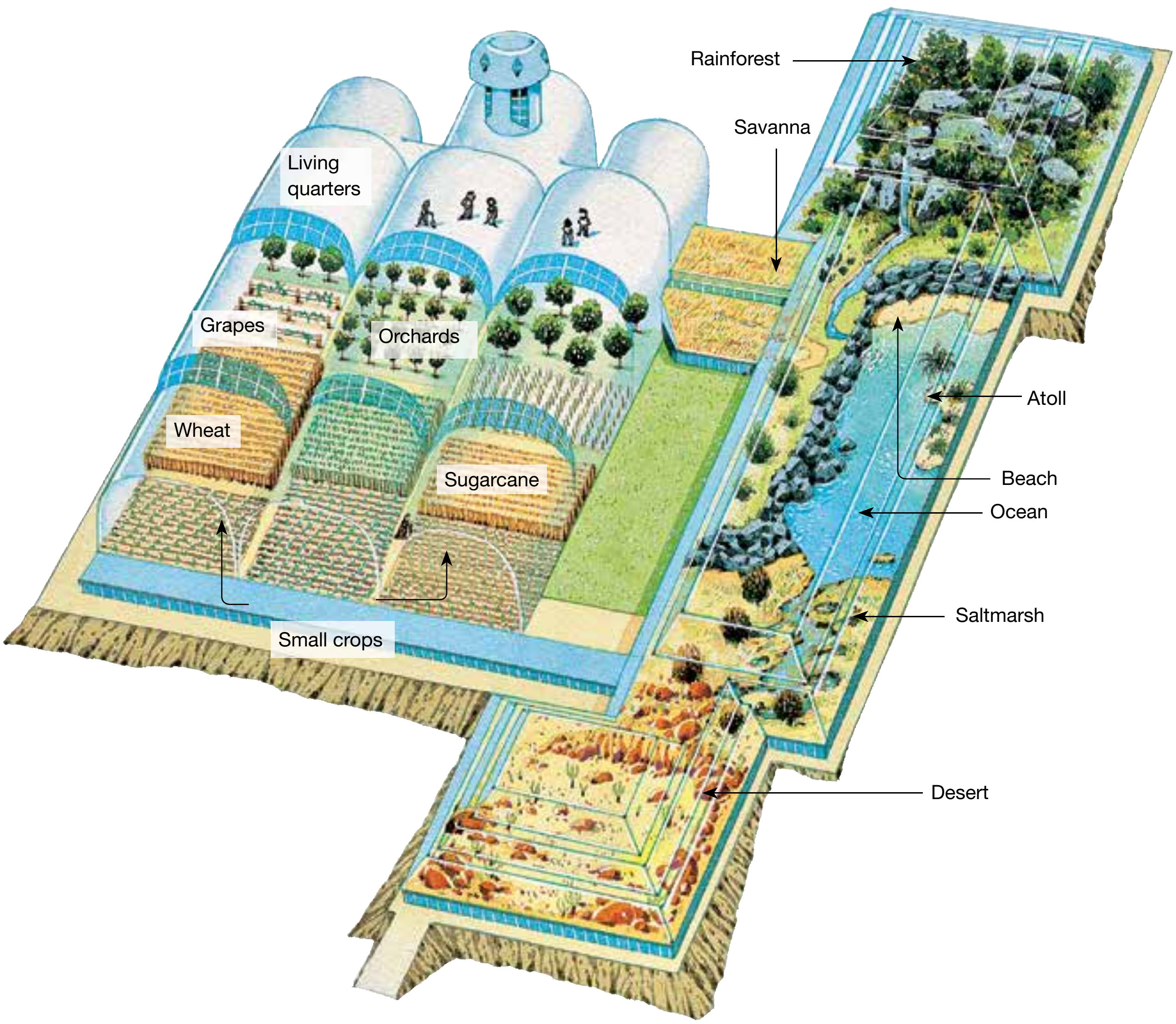
Biospherics is an exciting and essential new science. It was first envisioned by Vladimir Vernadsky in Russia in the 1920s. The biosphere project was inspired by John Allen, an American football player turned Beat poet (Johnny Dolphin), who had worked on a number of projects related to the synthesis of ecology and technology. In the early 1980s, along with several colleagues, he formed Space Biospheres Ventures. John Allen and his team designed and built an artificial world — Biosphere 2 — to develop a closed ecological system for research and education. Perhaps eventually this information will be used to sustain human life on other planets, such as Mars.

Biosphere 2, southern Arizona

14.10.2 What does it look like?

Biosphere 2 covers 13 000 square metres and contains living quarters and greenhouses containing food crops. Five different artificial environments are enclosed within the structure; a desert, a salt marsh, a tropical savanna, an ocean and a rainforest.

Plan of Biosphere 2. The glass and structure components acted as a filter for incoming solar radiation so that almost all UV radiation was absorbed.



14.10.3 What is it for?

Earth is a natural biosphere. The Earth's biosphere (Biosphere 1) has existed for at least 3.8 billion years. Some have called Biosphere 2 a type of cyber-Earth. Biosphere 2 is an artificially made structural biosphere located at an elevation of 1200 metres above sea level in a temperate desert region in southern Arizona, United States of America. Biosphere 2 was designed as an eco-technological model for space exploration and colonisation. This bioengineered facility was intended to grow food, cleanse the air, and recirculate and purify water for its inhabitants. This was to be achieved without exchange of materials (including atmospheric gases) with the outside world. The purpose of this cyber-Earth was for scientists to gather information to assist in the development of strategies to solve some of Earth's environmental problems and the hurdles of developing human colonies in space.

14.10.4 Closed systems

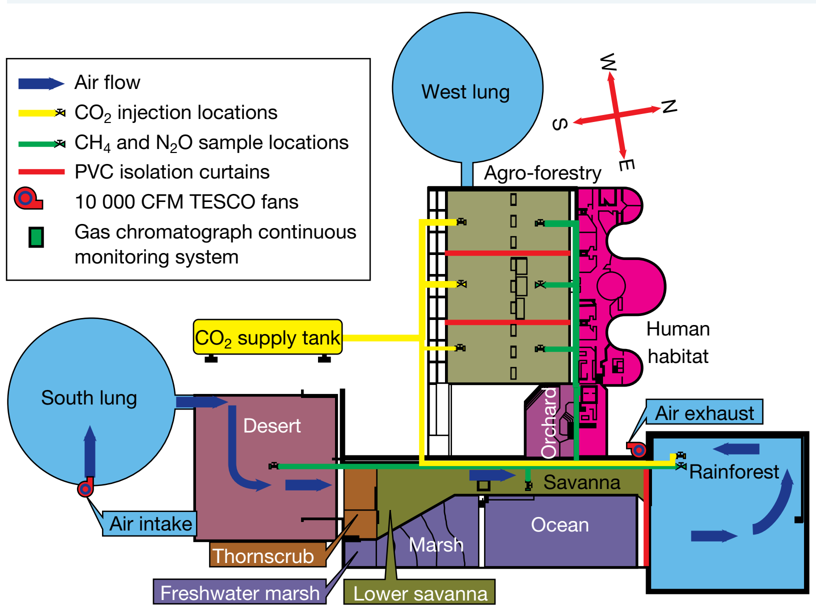
Biosphere 2 and Earth are similar because they are both closed systems. The space frame of Biosphere 2 has the same job as the Earth's atmosphere, which acts as a giant hollow globe that keeps the Earth a closed system. No event in a closed system (such as Earth's atmosphere or Biosphere 2's special frame) is isolated. If 40 people were to enter the desert biome of Biosphere 2, the sensors would quickly record a decrease in the oxygen levels and an increase in carbon dioxide levels throughout all of the biomes in Biosphere 2. This is because the people would breathe faster than the plants could take up the excess carbon dioxide. Could a similar thing happen outside Biosphere 2?

Abigail Alling stopped her graduate work at Yale University on blue whales to enter Biosphere 2 as the manager of oceans and marshes. She created and operated the world's largest artificial ecological marine system, a mangrove marsh and ocean coral reef, for the Biosphere 2 project. She was one of the original eight Biospherians to live inside Biosphere 2 — the artificial cyber-Earth system.

14.10.5 What happened?

Shortly after sunrise on 26 September 1991, eight people and 3800 species of plants and animals were locked inside this artificial world for two years. Worldwide, millions of television viewers watched. The crew had been prepared by years of training and working on developing systems for Biosphere 2. They had also had nine preliminary one-week semiclosed experiments over the previous five months.

Air flow and carbon dioxide movement through Biosphere 2



Gasping for oxygen

By the end of the first year of their mission, the Biospherians reported deteriorating air and water quality. Oxygen concentrations in the air had fallen from 21 per cent to 14 per cent. This oxygen level was barely enough to keep them alive and functioning. At the same time, carbon dioxide concentrations were undergoing large daily and seasonal variations and nitrous oxide in the air had reached mind-numbing levels. In January 1993, fresh air was pumped in to replenish the dome's atmosphere and rescue the inhabitants. Investigations indicated that the missing oxygen was being consumed by microbes in the excessively rich food crop soil.

It was very fortunate that the fresh concrete used in the structure's construction absorbed carbon dioxide released by microbial metabolism. If this carbon dioxide sink hadn't been available, the air would have become unbreatheable much earlier.

More carbon cycling

Due to a forceful El Niño current, one of Arizona's cloudiest seasons on record was experienced between October 1991 and February 1992. The carbon dioxide concentration inside Biosphere 2 rose to about 3400 ppm (parts per million). The combination of this effect and an unusually dark cloudy period in the last week of December greatly reduced photosynthesis. During this period, the rise in carbon dioxide to less than 4000 ppm was due to the operation of a recycler, which captured carbon dioxide and precipitated it into calcium carbonate (limestone). The calcium carbonate could later be released into the air by heating the limestone. This experience provided an insight into how to maximise photosynthesis and minimise soil respiration. Hence, Biosphere 2's goal to maintain its atmosphere was achieved despite the low light conditions.

Getting hungry

Ideally, the chemical-free agriculture system inside Biosphere 2 recycled all human and domestic animal waste products. It also initially included dozens of crop varieties to provide nutritional balance and allow for crop rotation. Biosphere 2, however, encountered considerable food production problems.

One article written about the Biosphere 2 project stated: 'Seal a group of scientists inside Biosphere 2, the futuristic glass-and-dome experiment, for two years and what do you get? Fights over food.' Comments from the Biosphere 2 botanist suggested that personality differences and crop failures made life difficult and that 'food distribution became a very tense issue . . . I think that made us all a little cranky, always being hungry'.

Due to unexpected crop failures, far less food was produced than had been projected. Only 60 per cent of the sunlight made it through the glass pane of Biosphere 2's space frame. Cloudy days also reduced the light available to plants for photosyntheses. A combination of unprecedented cloudy weather for the second straight year (20 per cent below the low rate of sunshine of 1992) and increased insect pest problems contributed to reduced food production.

An interview with one of the Biospherians in February 1992 described their surprise at their initial weight loss and desire for more food than they were supposed to have. They dipped into their stored food, believing that a better summer harvest would allow them to replenish it later. Unfortunately, the harvest did not improve. A lock was placed on the refrigerator to keep them from sneaking food. When the mission ended, the average weight loss per person was around 13 kg.

Survivors

Eighteen of the 25 introduced vertebrate species became extinct. All of the insect pollinators died, which prevented most plants from producing seeds. This led to food supplies falling to dangerous levels. Weedy vines flourished in the carbon-rich atmosphere and threatened to choke out more desirable plants. Although the majority of insects disappeared, ants and cockroaches thrived and overran everything, including workers.

14.10.6 The future

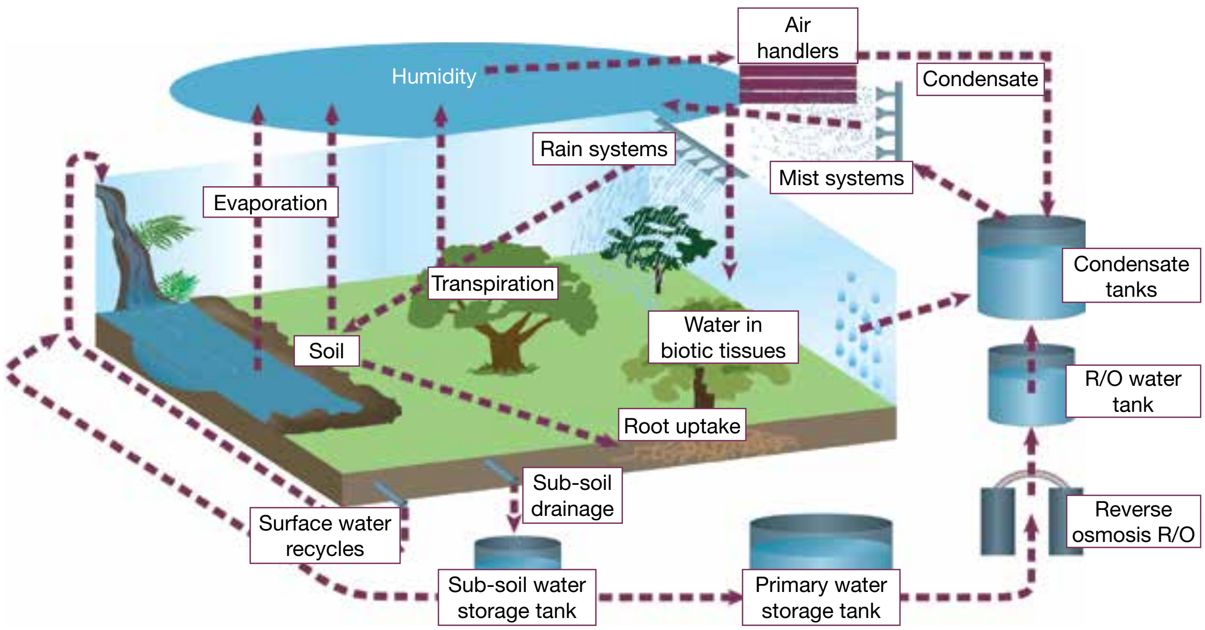
More recent plans for Biosphere 2 include flushing it with carbon dioxide and using it to predict the Earth's future.

As carbon dioxide is a fundamental requirement for photosynthesis, scientists have long suspected that higher carbon dioxide levels will fuel extra plant growth. Some of them have even suggested that rising carbon dioxide levels may boost global harvests. Other scientists have suggested that trees and shrubs around the world will help alleviate the problems of global warming by soaking up some of the additional carbon dioxide. This brings some thought-provoking questions to mind.

- If extra plant growth does appear, will all crop plants be affected in the same way; if not, what are the implications?
- If extra carbon is taken up by the natural biosphere, how long will it stay there?
- What would happen if the carbon dioxide quickly went into the soil and was then returned to the atmosphere?
- Will the carbon dioxide be safely locked up in the forests?
- Are there carbon dioxide levels that may kill off trees and shrubs, resulting in release of their accumulated carbon in one catastrophic burst?
- How long (and with what effects) can a group of people live in an artificial closed system?
- Does the experience of Biosphere 2 bring us any closer to living on Mars?

14.10.7 Water cycle

Water was conserved inside the Biosphere 2 wilderness environments. Condensation, artificial rain or irrigation (by sprinkler systems), evapotranspiration and sub-soil drainage were the major internal water cycling components. Water systems, however, became polluted with excess nutrients. This led to degraded aquatic habitats and contaminated drinking water supplies.



14.10 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. Why was Biosphere 2 not called Biosphere 1?
2. List the five different artificial environments enclosed within Biosphere 2.
3. What was the purpose of Biosphere 2?
4. State one way in which Biosphere 2 is similar to Earth.
5. Why would you expect an increase in carbon dioxide levels and a decrease in oxygen levels if a large number of people entered Biosphere 2?

6. Why was fresh air pumped into Biosphere 2 in 1993?
7. How did microbes affect the carbon dioxide levels?
8. Why was it fortunate that the fresh concrete in the structure absorbed carbon dioxide?
9. How did clouds affect food production?
10. How was water cycled through Biosphere 2?
11. Suggest ways in which the experience and findings of the Biosphere 2 project can be useful.

Think

12. Due to the moist, artificially generated climate, shrubs and grasses, rather than desert plants, overran the desert area.
    (a) Suggest why this occurred.
    (b) If you were the scientist assigned to solve this problem, suggest how you could increase the number of desert plants.
13. The rainforest in the Biosphere 2 prospered, doubling in size. Job's tears, a grass that normally grows about 60 centimetres tall in the tropics, became a giant of around 4 metres.
    (a) Suggest how this outcome could be advantageous to Biosphere 2.
    (b) Suggest how this outcome could be disadvantageous.

Create

14. Make a biosphere using a plastic soft drink container.
15. Imagine that you were one of the Biospherians. Write a diary about your two years in Biosphere 2.
16. Imagine you are one member of the first colony to live on Mars in 2020. Write a letter back to your family or friends about your new life.
17. Imagine that a meteor will hit Earth in two years' time and that all of human life needs to be moved off the planet by this time.
    (a) Make a list of all of the things that would be required to support human life.
    (b) Design a spacecraft that can meet these needs and keep you and your fellow travellers alive until you find (or can modify) a planet or environment that is inhabitable.
18. Imagine that the combination of the greenhouse effect and the hole in the ozone layer have made Earth uninhabitable. You need to design an artificial world that will meet your needs. What would it look like and how would it work?

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Try out this interactivity: The survival game (int-0217)

Complete this digital doc: Worksheet 14.5: Slowing global warming – alternatives (doc-12833)

Complete this digital doc: Worksheet 14.6: A dome away from home (doc-12834)

14.11 Project: The fifty years after

learnon

14.11.1 Scenario

- **260 million years BC:** A massive volcano in what is presently China erupts, causing atmospheric and oceanic changes leading to the extinction of 95% of life in the oceans and 70% of land-based life.
- **95 million years BC:** Undersea volcanic activity triggers a mass extinction of marine life and buries a thick mat of organic matter on the sea floor.
- **72 000 BC:** The Lake Toba volcano in Indonesia ejects nearly 3000 cubic kilometres of material into the atmosphere, cutting off much of the sun's light to the Earth's surface for so long that 50% of humanity dies out.
- **2000:** The UK science program *Horizon* uses the term supervolcano to describe volcanoes capable of massive eruptions covering huge areas with lava and ash and causing long-term weather effects and mass extinctions.

- **2030:** The supervolcano under Yellowstone National Park erupts cataclysmically, destroying half of the US and changing the Earth's atmosphere and surface conditions for centuries to come.
- **The year is now 2080.** Fifty years after the eruption, the gases and ash that the eruption produced, as well as the destruction of large sections of land, have affected the critical environmental cycles of the Earth's environments; and human civilisation has had to change its ways in order to survive. Some things remain the same though — we still have radio and television of a sort. Not surprisingly, with the fiftieth anniversary of the Yellowstone eruption (or 'Y-day', as it is known) coming up, lots of TV programs will be focusing on the critical event that changed our world forever.

14.11.2 Your task

As part of a small documentary film company, you will produce a 5-minute segment for a special edition of a TV science show that will be aired on the fiftieth anniversary of Y-day. In this segment, a science journalist will interview a variety of experts in a retrospective of what happened on Y-day, how the environment has changed over the 50 years since the eruption, and what humanity can expect to happen in the next 50 years.

14.11.3 Process

- Start your research. Make notes of material that you can use in your segment, including the short-term and long-term effects that a massive volcanic eruption would have on our environment, the types of experts that you would interview who could describe these effects, and what causes a super-volcano to form and erupt. You should each find at least two sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information.
- Film the scenes for your segment using a webcam, digital camera or camcorder.
- Use video-editing software such as Movie Maker to put the segment together for submission.

14.12 Review

14.12.1 Global systems

- provide examples of ways in which human activity has affected global systems **14.2, 14.3**
- **describe** the phosphorus and nitrogen cycles **14.2**
- **outline** the processes involved in the carbon cycle **14.2**
- show the interactions of the carbon, water, phosphorus and nitrogen cycles within the biosphere **14.2, 14.3, 14.4**
- **explain** the causes and effects of the greenhouse effect **14.4, 14.7**
- **distinguish** between the greenhouse effect and the enhanced greenhouse effect **14.4, 14.5, 14.7**

14.12.2 Biodiversity

- **define** the term 'biodiversity' **14.5**
- **distinguish** between genetic diversity, species diversity and ecological diversity **14.5, 14.9**
- **outline** some sources or causes of genetic diversity **14.9**
- suggest why species diversity is important to the survival of the species **14.9**
- suggest why biodiversity is important to the survival of a species **14.5, 14.9**
- suggest the link between biodiversity and evolution **14.9**
- consider the long-term effects of loss of biodiversity **14.9**
- **explain** the factors that drive the ocean currents, their role in regulating global climate and their effects on marine life **14.3**
- **outline** the effect of climate change on sea levels and biodiversity **14.3, 14.4, 14.5, 14.6, 14.9**
- comment on changes to permafrost and sea ice and the impacts of these changes **14.4**
- suggest how genetic characteristics may have an impact on survival and reproduction **14.9, 14.10**
- **describe** the process of natural selection using examples **14.9**
- **explain** the importance of variations in evolution **14.9**

14.12.3 Global systems and human impacts

- **outline** some human activities that are contributing to global warming **14.2, 14.4, 14.6, 14.7**
- **outline** some key issues of the climate change debate **14.7**
- **describe** examples of ways in which human activity has affected biodiversity **14.9**
- **evaluate** some strategies for addressing global warming **14.6**
- comment on the role of science in identifying and explaining the causes of climate change **14.8, 14.10**

Individual pathways

ACTIVITY 15.1	ACTIVITY 15.2	ACTIVITY 15.3
Revising global systems	Investigating global systems	Investigating global systems further
doc-10683	doc-10684	doc-10885

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online only

FOCUS ACTIVITY

Constantly changing physical, chemical and biological cycles have contributed to the survival of various forms of life on Earth. Our life-support systems are not in good shape.

Using knowledge that you have gained from this topic, comment on the statements above.

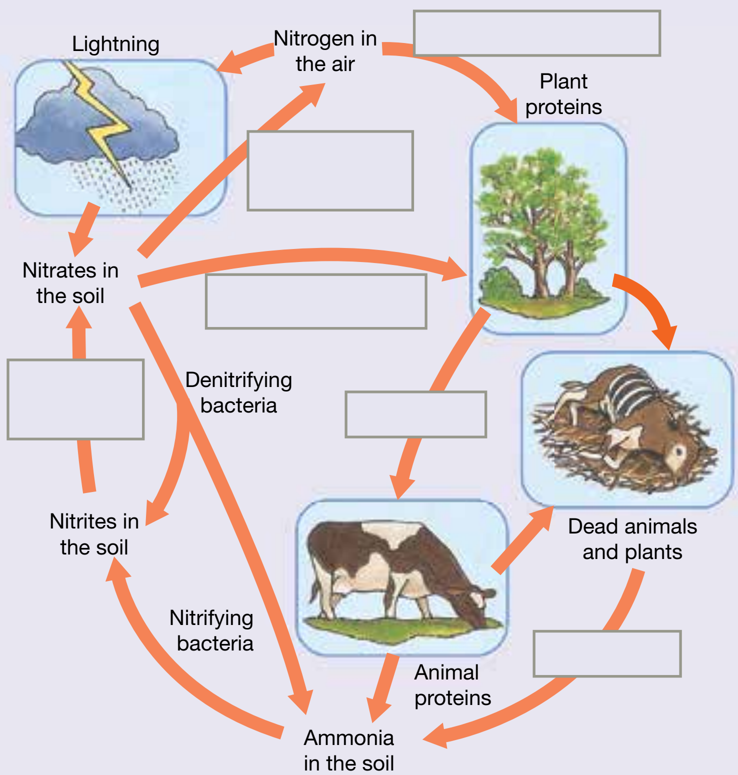
Access more details about focus activities for this topic in the Resources tab (doc-10682).

14.12 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Global warming is a current issue that is not going away.
   (a) **Outline** the most accepted view within the scientific community of the cause of global warming.
   (b) **Describe** examples of effects or consequences of global warming that have been suggested by scientists.
   (c) State your opinion about the possible (i) cause, (ii) effects and (iii) solutions for global warming.
   (d) View the top ten arguments about global warming that are most used by sceptics. Rank these statements in order of most like your opinion to least like your opinion. **Justify** your ranking.
   (e) State the difference between an opinion, a theory and a fact.
   (f) Can scientists have opinions? If you agree, when, how and why should these be shared? If you do not agree, why not?
   (g) Should science play a part in the making of climate policy? **Justify** your response.
   (h) Suggest possible reasons for the climate debate.
2. **Demonstrate** your understanding of the following groups of terms by using a visual thinking tool to show the links between them.
   (a) Species, biodiversity, biodiversity loss, threatened, endangered, extinct, mass extinction
   (b) Biosphere, lithosphere, hydrosphere, biota, atmosphere, troposphere, stratosphere
   (c) Atoms, molecules, organelles, cells, multicellular organisms, species, population, ecosystem, biosphere
   (d) Stratosphere, climate change, greenhouse gas, fossil fuels, global warming, carbon dioxide, methane, nitrous oxide, biodiversity loss, enhanced greenhouse effect, cellular respiration, lithosphere
   (e) Carbon cycle, photosynthesis, cellular respiration, carbon dioxide
   (f) Water cycle, precipitation, transpiration, evaporation, hydrosphere
   (g) Ozone layer, ozone hole, CFCs, stratosphere
   (h) Abiotic factor, biotic factor, temperature, rainfall, climate, multicellular organism, ecosystem, biome
   (i) Greenhouse effect, enhanced greenhouse effect, global warming

3. What is meant by biodiversity and why is loss of biodiversity a concern?
4. (a) The mountain pygmy possum is restricted to an area of 6 km^2 in the Australian Alps. Suggest how such a restricted habitat may influence its chances of survival.
   (b) Suggest abiotic and biotic factors that may affect this possum.
   (c) Suggest how warmer temperatures and reduced snow may affect its lifestyle. Be specific in your response by including examples of different scenarios.
   (d) What is meant by the term *extinction*?
   (e) If this species was to become extinct, suggest implications to other organisms within its ecosystem.
5. Copy the figure at right into your workbook and then use the following terms to complete the links: nitrifying bacteria, uptake by roots, denitrification, decomposition, feeding, nitrogen-fixing bacteria.



6. Rising sea levels and saltwater intrusion associated with climate change are threats that Kakadu National Park is experiencing.
   (a) Suggest why these threats are associated with climate change.
   (b) Suggest effects that these new threats may have on the (i) biotic and (ii) abiotic parts of this ecosystem.
   (c) Suggest actions that could be taken to reduce the loss of biodiversity within Kakadu National Park.
7. Agriculture has had (and continues to have) a devasting effect on a number of marine ecosystems. Hypoxia in coastal zones from nitrogen and phosphorus outputs of agricultural and livestock industries is one such example.
   (a) Using your knowledge of the nitrogen and phosphorus cycles, **explain** how these outputs may damage marine ecosystems.
   (b) Suggest strategies that may reduce the negative impact that agriculture has on our ecosystems.

Test yourself

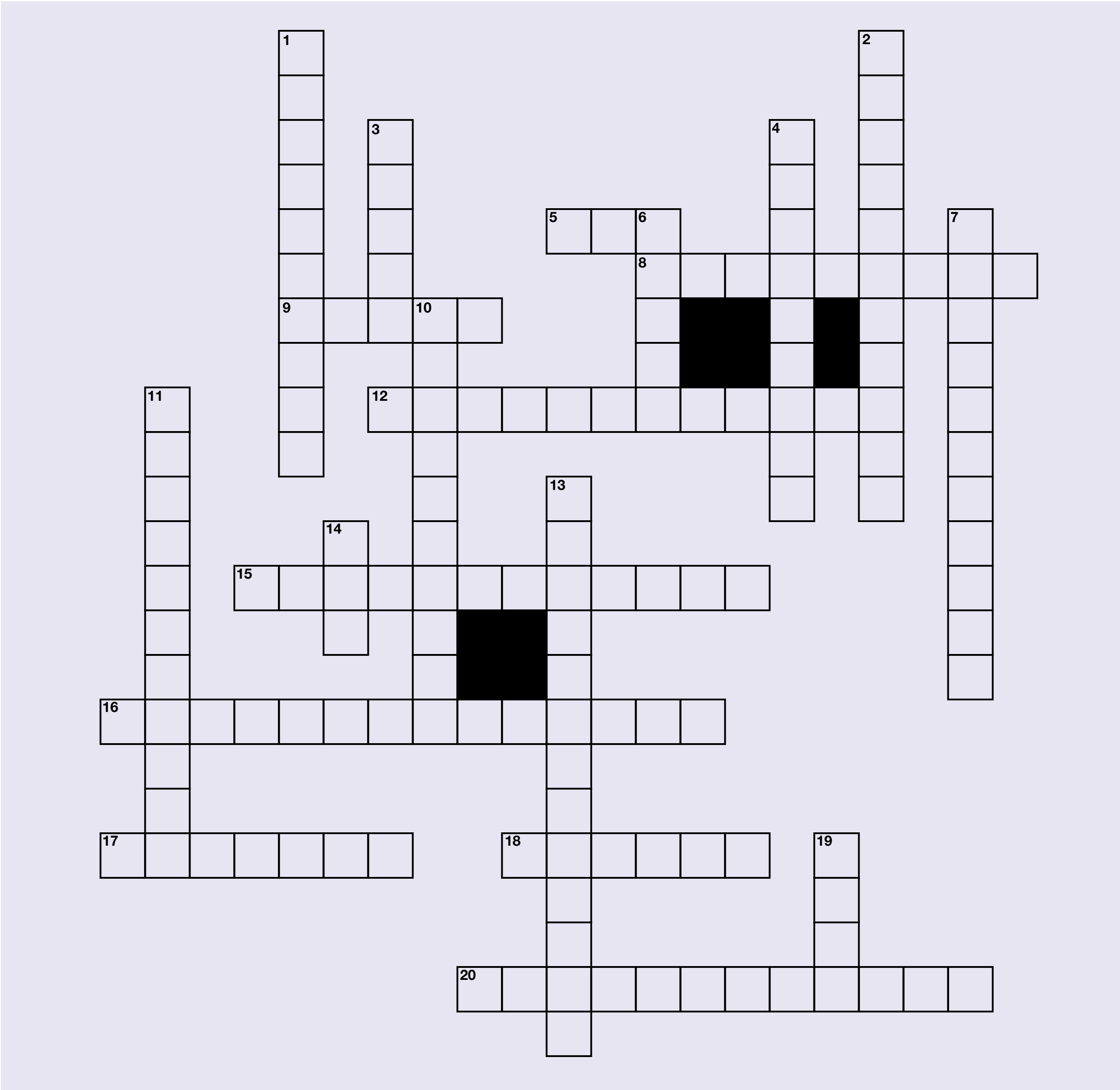
1. The amount of warming that results from a given increase in atmospheric carbon dioxide is referred to as:
   (A) global change.
   (B) climate sensitivity.
   (C) the heat stress threshold.
   (D) geosequestration. **(1 mark)**
2. In the 1980s, it was found that ozone in the atmosphere was being depleted by:
   (A) UV radiation.
   (B) chlorofluorocarbons.
   (C) hydrofluorocarbons.
   (D) carbon dioxide. **(1 mark)**
3. The most recent mass extinction was the
   (A) late Devonian.
   (B) Cretaceous-Tertiary.
   (C) late Triassic.
   (D) Permian-Triassic. **(1 mark)**
4. Regions are divided into biomes based upon
   (A) the type of vegetation that is dominant.
   (B) the amount of rainfall that is received.
   (C) the number of different organism populations that are present.
   (D) their latitude and longitude. **(1 mark)**
5. Complete the crossword on the next page without referring to your text. Crossword clues are provided below. **(6 marks)**

Across

5. Abbreviation of chlorofluorocarbon
8. Dynamic system of organisms interacting with each other and their environment
9. Planting these may help reduce the effect of global warming.
12. The ozone layer is located in this part of the Earth's atmosphere.
15. These bacteria convert nitrates in soil and water into nitrogen in the air.
16. Plants use this process to make glucose and oxygen.
17. An example of a greenhouse gas
18. Photosynthesis, respiration, death and decomposition are all processes within this cycle.
20. This term relates to the total variety of living things on Earth.

Down

1. A group of organisms of the same species in the same area
2. Includes water and dissolved carbon dioxide
3. A layer of this gas helps block out more than 95 per cent of ultraviolet rays entering the atmosphere.
4. The life-support system of our planet
6. Organisms are composed of these.
7. Global warming will lead to a rise in this factor.
10. The loss of a species from Earth
11. Includes rocks, coal and oil deposits, and humus in soil
13. This human activity can result in increased carbon dioxide levels in the atmosphere.
14. Abbreviation of deoxyribonucleic acid
19. Abbreviation of total ozone mapping spectrometer



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Complete this digital doc: Worksheet 14.7: Global systems: puzzles (doc-12835)

Complete this digital doc: Worksheet 14.8: Global systems: summary (doc-12836)

TOPIC 15 Student research project and skills

15.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

15.1.1 Why learn this?

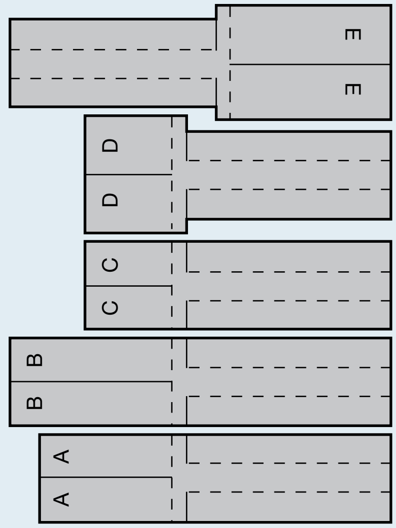
Previously you probably com pleted a student research project which involved designing and carrying out your own investigation. It's time to have another go! You will be using many of the skills you learned in stage 4. In this topic we will extend these skills and apply them to more complex problems.

LEARNING SEQUENCE

INVESTIGATION 15.1

Paper helicopter

AIM: To investigate variables that affect a helicopter's drop speed

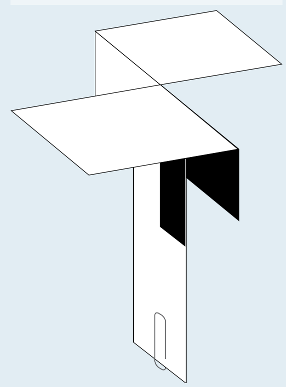


You will need:

stopwatch
ruler
paperclip
a copy of the helicopter cut-outs

- You will need to work in groups of three for this experiment.
- Before cutting out the helicopters, copy the table below into your exercise book and fill in the first three columns.
- Cut out the helicopters (cut along solid lines only), then fold along the dotted lines. Fold one blade in one direction and the other in the opposite direction.
- Attach a paperclip to the bottom of the helicopter. This will weigh it down and hold the flaps in place. The diagram below right shows what the helicopter should look like.
- Find an elevated place to drop your helicopters. A balcony or open window on the second floor of your school would be ideal. One student from each group should be at the dropping point at the top. Two students from each group will need to be at the landing point at the bottom.
- Drop the helicopters one at a time and use the stopwatch to time how long it takes for each helicopter to reach the ground. After you have dropped all of the helicopters, one student will need to walk them upstairs for the second trial. Each helicopter will need to be dropped five times. As the helicopters fall, record any other relevant information. For instance, you may wish to record whether the helicopters spin as they fall.

A finished helicopter



Discussion

1. Write an aim for this experiment.
2. Calculate the average time taken for each helicopter to fall.
3. List all the variables that may affect the time taken for the helicopters to land.
4. In this experiment two variables were deliberately changed: the length of the blades and the width of the blades. In what way is this different to most experiments you have done in science?
5. Which pairs of helicopters could be compared to find out the effect of the width of the blades on the drop time?
6. Which helicopters could be compared to find out how the length of the blades affects drop time?
7. Write two separate conclusions about the effect of blade width and blade length on the helicopter drop time.
8. Discuss the validity of this experiment. *(Hint:* Are there any variables you were not able to control?)
9. Why was the experiment repeated five times?

			Time taken to reach the ground (s)						
			Trial						
Helicopter	**Width of blades (cm)**	**Length of blades (cm)**	**1**	**2**	**3**	**4**	**5**	**Average**	**Other observations**
A									
B									
C									
D									
E									

15.2 Before you start: safety and ethics

15.2.1 Safety first

When deciding on a research question for a student research project there are two very important things to think about: safety and ethical considerations. If the project you are planning to do is not safe or raises ethical issues such as cruelty to animals, your teacher is unlikely to let you do the project.

The most important thing to consider when planning an investigation is safety. Your teacher will probably expect you to submit a risk assessment before you can start your investigation. A risk assessment is a document where you list the hazards associated with an activity and how you plan to minimise these. If the risk associated with an experiment is too high, you will be asked to modify your plan. On the next page you can see part of a sample risk assessment for a class experiment. It was prepared by a teacher using software called riskassess. You probably will not be required to prepare such a detailed risk assessment.

15.2.2 Hazardous substances

Hazardous substances are chemicals that are harmful to humans. The harmful effects might be seen straight away, or over a long period of time. If you get concentrated sulfuric acid on your skin you will feel it burning and blisters will form rapidly. Some substances do not appear harmful at first but repeated exposure can affect health over time. Carcinogenic substances are substances that cause cancer. Their effect may take many years to show up. Before using any chemical in an investigation you need to be aware of any associated hazards.

Safety data sheet (SDS)

Manufacturers that supply chemicals to schools and other organisations are required to supply a safety data sheet (SDS) with the chemicals they sell. The SDS is also available online. An SDS provides information about any health risks associated with a chemical, guidelines for safe storage and handling, and information about what to do if the chemical is spilt or comes in contact with the skin or eyes. Disposal information is also provided. Schools and other businesses that use chemicals (including those used for cleaning) are required to have the SDS for the chemicals they store readily available, either in printed form or electronically. When writing your risk assessment for your student research project you could consult the SDS for any chemical you are intending to use. They are lengthy documents, however, and your school may have a summary of the safety information about chemicals available in other forms such as risk assessment software.

A picture is worth a thousand words

Another way to convey safety information is through the use of pictograms. The symbols on page 606 are used as warnings on chemicals and other materials and devices. You may have seen different safety symbols used, but the pictograms on page 606 are part of the Global Harmonised System (GHS) system of classification and labelling of chemicals and by 2016 they were the standard symbols used in Australia.

Hazardous substances and risk assessment

If your investigation involves the use of hazardous substances, you will need to include this in your risk assessment. Your risk assessment should list any hazardous substances you plan to use, as well as any hazardous substances that may be produced in your investigation. For example, if you burn sulfur powder, sulfur dioxide gas is produced. Sulfur dioxide is a toxic gas, so it needs to be included in the list. Once you have listed all the substances, you need to look up the safety information for each and note the risks associated with each substance. You then need to think about how you will minimise these hazards. The main risk associated with sulfur dioxide is that it is toxic by inhalation. It can cause breathing difficulties, A section of a risk assessment prepared with a risk assessment software package

RISK ASSESSMENT **Our Lady of Mercy College Parramatta**

Investigation 13.3

Written by: Pascale Warnant **Commenced on:** 28 Sep 2012 **Expires:** 28 Dec 2013

Classes for which experiment is required

Teacher: Pascale Warnant (user code 1) **Year Group:** 9

Room	Period	Date
Lab 6	7	Mon 3/9/12

Items to be prepared by laboratory technician (user code 2)

- hotplate
- geranium leaves
- methylated spirit
- chromatography paper

Procedure or reference, including variations

p. 392 of CS5

Equipment to be used

chromatography paper

Potential hazards
Flammable.

electric hotplate

Potential hazards
IGNITION SOURCE, unless specially designed and certified. Do not heat flammable liquids on a hotplate that is not certified as sparkproof. Hotplate retains heat; possibility of burns. Damaged electric cord may cause electric shock.

Standard handling procedures
Inspect regularly for signs of damage to cord, cord loose in plug, cord loose at entry to hotplate, or any signs of corrosion or other damage. Test and tag at regular intervals.

Chemicals to be used and produced

ethanol CH_3CH_2OH

(ethyl alcohol, alcohol, absolute alcohol, methylated spirits, duplicating fluid, duplicator spirit, Fordiograph fluid)

Class: 3 PG: II **7-12** Users: 1,2,3,4,5 UN: 1170 CAS: 64-17-5

Potential hazards
HIGHLY FLAMMABLE; DO NOT USE NEAR IGNITION SOURCES; slightly toxic; prolonged contact with skin causes irritation. Forms violently explosive mixtures with nitric acid and other oxidising agents. Reaction of ethanol with acidified dichromate solution is highly exothermic. Potassium reacts violently with ethanol. Do not heat ethanol in a container over an open flame; use a water bath that is sparkproof. Any experiments involving the combustion of ethanol are potentially hazardous. If a fuel is required, use metaldehyde or hexamine tablets. Ethanol becomes less flammable as it is diluted with water; 50% ethanol is barely flammable at room temperature and <24% ethanol is not classified as a dangerous good.

Standard handling procedures
Store and use away from ignition sources. Methylated spirits is the usual form in which ethanol is obtained; it contains methanol (5%), water (5%) and small amounts of pyridine and other coal-tar products to make the liquid unpalatable. Methylated spirits is adequate for most experiements carried out in schools.

Others

geranium - should not be eaten

Knowledge

I have read and understood the potential hazards and standard handling procedures of all the equipment, chemicals and living organisms.
I have read and understood the Material Safety Data Sheets for all chemicals used and produced.
I have copies of the Material Safety Data Sheets of all the chemicals available in or near the laboratory.

Risk assessment

I have considered the risks of:

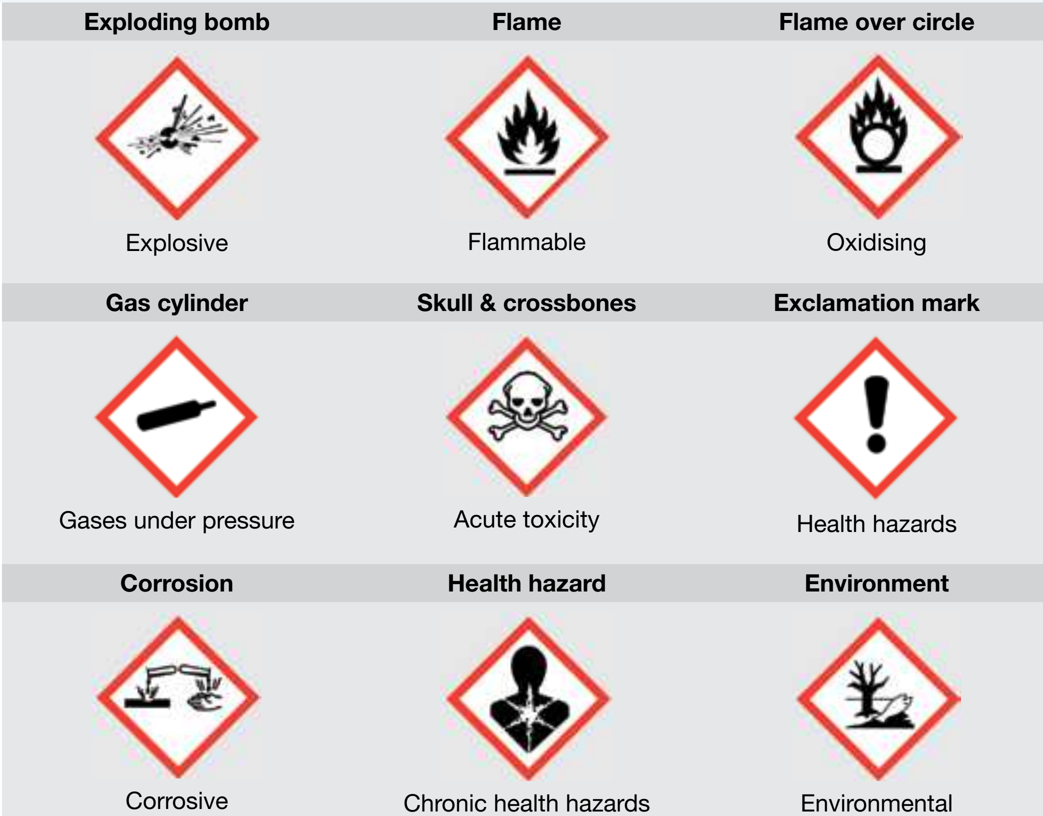
fire	breakage of equipment	electrical shock	radiation
explosion	cuts from equipment	escape of pathogens	waste disposal
chemicals in eyes	sharp objects	heavy lifting	inappropriate behaviour
inhalation of gas/dust	rotating equipment	slipping, tripping, falling	special needs
chemicals on skin	vibration and noise	falling objects	other risks
runaway reaction	pressure	heat and cold	

Certification by teacher

I have assessed the risks associated with performing this experiment in the classroom on the basis of likelihood and consequences using the School's risk matrix, according to International Organization for Standardization Standard ISO 31000:2009 and the Risk Management Guidelines, HB 436:2004.

particularly for people who have asthma. The gas can also irritate the eyes. To minimise these risks, the experiment could be done in a fume cupboard and with the classroom windows open or classroom extraction fans turned on for good ventilation.

The GHS pictograms



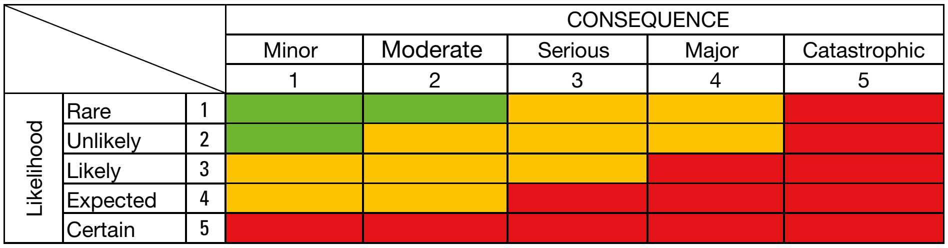
Other hazards

Even if you are not planning to use hazardous substances in your investigation it is likely that there are other hazards associated with your experiment. Some risks relate to the equipment you use and minimising the risk involves using the equipment in a safe manner. A Bunsen burner, scalpel or even scissors can be hazardous if used incorrectly. When assessing risk you should consider who will be using the equipment and whether they are properly trained to use it. Risks can also result from the setting up or dismantling of equipment, and from allergic reactions. Using latex gloves to carry out a dissection is a sensible safety precaution for most students, but not for a student who has an allergy to latex. For some investigations it may also be necessary to consider the emotional impact of the investigation on the test subjects. Testing the impact of horror movies on heart rate may pose too high a risk if the test subjects are primary school students for example.

15.2.3 Too high a risk?

Once you have identified all the risks associated with your investigation, you should assess the inherent level of risk for the activity. Grids such as the one on the next page are useful to do this. If you cannot bring the risk level to the acceptable range (by wearing protective gear, for example), then you should modify your investigation plan.

A risk assessment matrix



Harm occurrence likelihood levels

- Certain: will occur on every occasion
- Expected: is expected to occur in most circumstances (e.g. more than 2 times a year)
- Likely: could occur in many circumstances (e.g. probable to happen up to 2 times a year)
- Unlikely: could occur occasionally (e.g. possibility of happening once a year)
- Rare: not expected to happen, but is possible (even if no occurrence registered)

Harm severity levels

- Catastrophic: multiple deaths
- Major: possibility of death or major permanent loss of function (motor, sensory, physiologic or intellectual)
- Serious: major injury/adverse health outcome (e.g. possibility of permanent lessening of bodily functioning)
- Moderate: moderate injury/adverse health outcome (e.g. increased length of stay)
- Minor: no or minor injury/adverse health outcome

Estimated risk levels: Red: unacceptable risk Yellow: tolerable risk Green: acceptable risk

15.2.4 Ethics

Ethics deal with moral values and a sense of what is right or wrong. Some ethical values are fairly universal. That means that they are accepted by most people worldwide. Most people throughout the world would agree that murder is wrong and looking after the old and sick is right. Many ethical values vary between countries, religions, different groups in societies or even between members of the same family. This is where things become tricky. A scientific investigation or use of technology that may be perfectly acceptable to some people may deeply upset others. The news stories below are a few examples.

SCIENTISTS ADD JELLYFISH GENE TO MONKEYS

Japanese scientists have produced the world's first transgenic primates, a monkey that has a gene which makes its skin glow fluorescent green. The fluorescence is the result of a jellyfish gene. The gene has been added to the monkey's cells at the embryo stage and the scientists have shown that it can be passed on to the next generation when the monkey reproduces. Previously it had been possible to insert genes from other species into the DNA of certain monkey cells, but these genes were not inherited by the next generation.

This research shows that it should be possible to create monkeys with genes from various other species, including human genes, and that these genes could be inherited. It may be possible to produce breeding colonies of monkeys with human genetic disorders and then use these monkeys to learn more about these disorders and try to find a cure. This is already being done with rats, mice and other rodents, but monkeys are more similar to humans. This is important because many disorders such as Alzheimer's and Parkinson's are too complex to reproduce in rodents.

There are fears, however, that this type of research could be used to create genetically engineered humans, with genes from other species. Some scientists are also concerned about the welfare of the animals used for this type of research.

Newborn transgenic marmoset Kei, left, and Kou. The green glow on the soles of their feet is the result of a jellyfish gene.

ARTIFICIAL LIFE WARNING: HOW IT COULD GET OUT OF CONTROL

Craig Venter, a researcher and co-author of the first sequencing of the human genome, has unveiled his latest invention: he has made a living cell. It is similar to a bacteria and, like bacteria, it can replicate. Cells such as these could be designed to have particular characteristics. They could have genes which give them the ability to produce biofuels or break down harmful chemicals.

Venter has been accused of playing God. There are concerns that human-made cells could mutate and spread out of control in the environment or be used as biological weapons.

Discussion

After reading the two articles, answer the following questions:

1. Do you think this type of research should be carried out? Give reasons for your answer.
2. Who should decide what type of research is allowed?

Ethics and your SRP

You may need to consider ethical issues if your SRP involves the use of animals or human subjects. Any SRP that involves cruelty to animals is unlikely to be approved by your teacher. If you are planning to do tests or surveys on other people, think carefully about the wellbeing of your test subjects. Your SRP should not involve harming others physically or emotionally in any way.

HOW ABOUT THAT!

A gut feeling

When Barry Marshall and Robin Warren came to the conclusion that stomach ulcers were probably caused by a bacteria, they were faced with some tricky ethical and safety considerations. A stomach ulcer occurs when the lining of the walls of the stomach becomes damaged and the acid inside the stomach eats away at the stomach wall. It is a very painful condition. Previously it was thought that ulcers were caused by lifestyle factors, including stress, so it was difficult to treat ulcers. People were usually told to avoid stress, for example, by changing their job or cutting their work hours, and to cut out particular foods, sometimes with no improvement to their health.

Barry Marshall and Robin Warren suspected that ulcers were actually caused by bacteria called *Helicobacter pylori*. They had found this bacteria in the stomach of people suffering from stomach ulcers but not in the stomach of healthy individuals. They had also studied the bacterium. The only way to know for sure would be to deliberately infect someone with the bacteria and find out if they developed a painful ulcer. There were risks involved; for instance, the bacteria could cause other health problems. It could even kill the patient. There were also ethical issues associated with deliberately trying to make a healthy person sick. In the end Barry Marshall carefully weighed up the risks involved and decided to test his hypothesis on himself. He swallowed a solution of the bacteria and soon became ill and developed the early symptoms associated with the development of stomach ulcers. He then treated himself with antibiotics. Now when a patient is diagnosed with a stomach ulcer, treatment is simple — a course of antibiotics usually fixes the problem.

Helicobacter pylori bacteria in the human stomach cause stomach ulcers. They move their hair-like structures to travel around the stomach lining.

15.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the following terms: 'risk assessment', 'SDS', 'carcinogenic' and 'ethics'
2. **Explain** what minimising risks means.
3. (a) What do the following symbols represent in the GHS pictograms?
   (i) An exclamation mark
   (ii) A skull
   (b) **Describe** the GHS pictogram that indicates:
   (i) a corrosive substance
   (ii) gases under pressure.
4. Extract the answers to the following questions from the risk assessment shown on page 605.
   (a) What is the main hazard associated with this experiment?
   (b) How will the teacher minimise the hazard?
   (c) Which protective gear will need to be worn when doing this experiment?

Think

5. **Explain** why it is important for an organisation to have access to the SDS for the chemicals they use and store.
6. The introduction of the Global Harmonised System of classification and labelling of chemicals in Australia has meant that many work places have had to change many of their labels and signs. **Outline** some of the advantages and disadvantages of adopting a global system of classification and labelling of chemicals.
7. **Describe** the safety and ethical issues associated with the experiment carried out by Barry Marshall.

Discuss

8. In small groups **discuss** the following statements:
   (a) Cosmetics should never be tested on animals.
   (b) All medical research including research into new drugs should be done by non-profit organisations rather than by companies out to make a profit.
   (c) Food made from genetically modified crops should have a special label to show that it contains GM ingredients.

Investigate

9. Find other examples of scientific research that raise ethical questions.

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Complete this digital doc: Worksheet 15.1: Safety (doc-12837)

15.3 Planning your investigation

15.3.1 Finding a topic

Your teacher will probably ask you to submit a plan before you start on your investigation. In your plan you will need to state the problem you want to investigate and provide an outline of the procedure you will use. After reading your plan, your teacher may suggest modifications to your investigation. In this subtopic are some of the steps involved in writing a plan for your SRP, although your teacher may ask you to use a different format.

Your investigation is much more likely to be of high quality if you choose a topic that you will enjoy working on. These steps might help you choose a good topic.

1. Think about your interests and hobbies. They might give you some ideas about investigation topics.

Think about your interests.

Think about your hobbies.

2. Make a list of your ideas.
3. Brainstorm ideas with a partner or in a small group. You might find that exchanging ideas with others is very helpful.
4. Find out what other students have investigated in the past. Although you will not want to do exactly the same topics, investigations done by others might help you to think of other ideas.
5. Do a quick search in the library or at home for books or newspaper articles about topics that interest you. You might also find articles of interest in magazines or journals. You could use a table like the one below to organise your ideas.

Brainstorm your ideas with others.

Topic area	**Name of book, magazine, website etc.**	**Chapter or article**	**Topic ideas**

15.3.2 From observations to ideas

Many ideas for scientific investigations start with a simple observation. Some well-known investigations and inventions from the past started that way. The development of penicillin was the result of a chance observation of a mould growing in a dish of bacteria. The bacteria near the mould were not multiplying. This observation was made by a Scot, Sir Alexander Fleming, in 1928. An Australian, Howard Florey, saw the possibility that the mould could be used to treat infections caused by bacteria. After almost 20 years of further investigation, the mould, called *Penicillium*, was used to produce penicillin. This is a powerful drug that can rid the body of many infectious diseases.

Danish scientist Hans Oersted discovered the connection between electric current and magnetism when, in 1819, he noticed that a compass needle pointed in the wrong direction every time it was placed near a wire carrying an electric current. His discovery started a flood of inventions, including electric generators and motors.

An investigation by 15-year-old student Catherine Pippos began with an observation that her friends seemed to perform better in track and field events when there was an audience cheering them on. You have probably seen this yourself. Her investigation 'Does an audience affect the performance of an athlete?' involved three different sporting activities and compared the performance of a large group of students under three different conditions:

- no audience
- a quiet audience
- a cheering audience.

The sporting activities were:

- goal shooting in basketball
- sit-ups
- shot put.

What do you think she found out? Perhaps you could try a similar investigation.

Could an audience really affect this athlete's performance? To answer the question scientifically an investigation is needed.

15.3.3 Defining the question

Once you have decided on your topic, you need to determine exactly what you want to investigate. It is better to start with a simple, very specific question than a complicated or broad question. For example, the topic 'earthworms' is very broad. There are many simple questions that could be asked about earthworms, such as:

- Which type of soil do earthworms prefer?
- How much do earthworms eat?
- Do earthworms prefer meat or vegetables?
- How fast does a population of earthworms grow?

Your question needs to be realistic. In defining the question you need to consider whether:

- you can obtain the background information that you need
- the equipment that you need is available
- the investigation can be completed in the time you have available
- the question is safe to investigate.

At this stage you should start using a logbook to keep a record of your investigation. Make sure you document how you decided on your research problem in your logbook and record the details of all books, websites and other resources you used to help you with your decision.

There are many problems relating to earthworms that could be investigated in an SRP.

15.3.4 Setting up your logbook

A logbook is a lot like a journal. It contains dated entries where you can document your thinking and planning, as well as your research and the results of any experiment you carry out. Anytime you work on your SRP, you should make an entry in your logbook. You should start your logbook at the very beginning of your project. The first entry might be a mind map or brainstorm that you have used to try to come up with a project topic, or it might be a timeline that you will use to keep yourself on task.

Below are some things you should include in your logbook:

- evidence of the thought process you went through to select your topic (e.g. list of possible topics, brainstorm, mind map etc.)
- evidence that you planned your use of time (timeline, list of deadlines etc.)
- notes from your background research. This includes conversations with teachers or experts as well as library research. Don't forget to write down the details you will need for your bibliography. You may wish to attach photocopies or printouts of material you read.
- evidence of the thought process you undertook to design your experiments (sketches, drafts of methods, revisions made and the reason why you modified your method(s))
- raw results for any experiments you carried out
- evidence of the planning of your final report and/or presentation.

Using a blog as a logbook

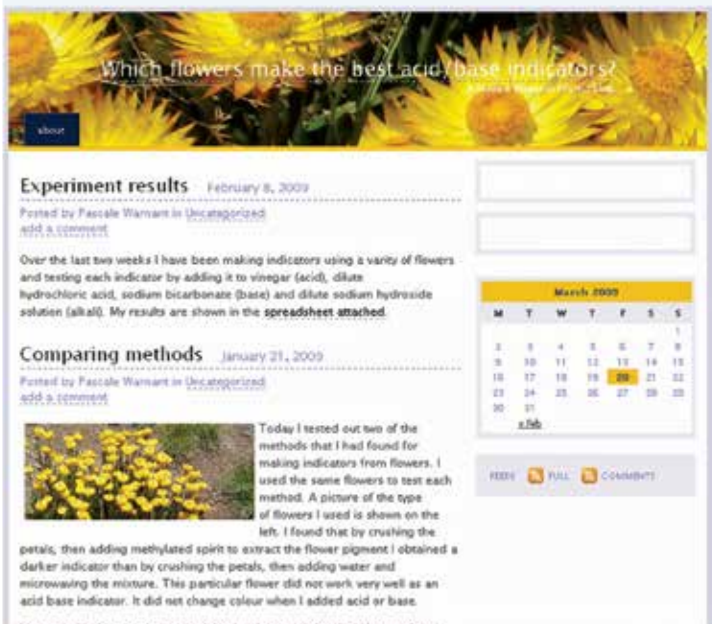
A blog or web log is a great way to present your logbook. Many sites will let you set up a blog for free. Once your blog is set up, each time you make a post it will automatically be dated. The advantage of a blog over a paper logbook is that you can upload documents as well as pictures and short videos and link them to your blog. You can also add links to other sites. Your friends, teachers and family can visit your blog and post comments about your work.

Staying safe online

A blog is a fantastic way to share your enthusiasm about Science. Publishing your work online does have some drawbacks, however. It makes your work more public than a paper logbook. When you create your blog, check who has access to it. Can the whole world see your blog or is it accessible only to students at your school? If your blog is on the internet follow these tips to keep yourself safe:

- You wouldn't put a photo of yourself with your full name, address, phone number and school in the newspaper would you? You could have anyone ringing you or turning up at your place or school to find you. For the same reason it is not a good idea to put too much information about yourself online.
  - If your blog is on the internet it will become part of your 'digital footprint' — the information about you that can be accessed on the internet. If you have a Facebook page, a Tumblr account, a YouTube channel or any other account that you use to share photos, videos or anything else about yourself these are also part of your digital footprint. Think carefully about what you upload to the internet and whether you provide details such as your full name, information about the school you attend (including photos that show your school uniform) and where you live. Depending on your blog's privacy setting it may be preferable to use only photos or narrated videos of your experiment rather than a video of yourself talking about the experiment.
  - If you do post photos or videos of yourself online, make sure that your clothing and other information on your

A blog used to document progress on a student research project. Use the SRP blog weblink in the Resources tab to access this blog.



blog passes the 'Nanna test': would you be embarrassed if your Nanna (or Pop, or auntie) came across your blog? If you would be embarrassed do not post it online!
  – Ensure your blog posts relate to your SRP only. Do not post information about what you do in your spare time, for example.
- Depending on the type of blog you set up you may be able to choose certain privacy settings. It may be possible to set up your blog so that only your school community can see it. This is the safest option. If this setting is not available you could password protect your posts so that they can be seen only when the correct password is entered. This is a good option if you do not want your work or photos to be visible to strangers. Check with your teacher to find out which settings he or she recommends.

15.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. What does SRP stand for?
2. Choosing a problem or question to investigate in your SRP does not mean the same thing as choosing a topic for your SRP. **Distinguish** between a question or problem and a topic.
3. **Define** the following terms: 'brainstrom', 'logbook', and 'blog'.
4. List some of the sections that are often included in a SRP plan.

Think

5. **Discuss** the advantages and disadvantages of scientists using a blog to document their research.
6. Five topics are written below. Write down three student research project questions for each topic.
   (a) High jump
   (b) Chocolate
   (c) Crystals
   (d) Seed germination
   (e) Energy conservation
7. Kiara told her teacher 'getting us to write a plan is a waste of time, we should be able to start on our project straight away'. **Discuss** whether you agree with Kiara's statement.
8. The television show *Mythbusters* involves a team led by Adam and Jamie carrying out investigations to test various myths. To see a list of the myths they have tested over the years and the outcomes of their tests use the **Mythbusters** weblink in the Resources tab.
   (a) **Define** the term 'myth' (use a dictionary if necessary)
   (b) Look at the list of myths Adam and Jamie have investigated and pick at least three that you could test using equipment available at home or at school.
   (c) If your school has any episodes of *Mythbusters* available watch an episode. Make a list of the myths tested in the episode and discuss the validity of the experiments carried out by Adam, Jamie and their team.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: Mythbusters

Explore more with this weblink: SRP blog

Complete this digital doc: Worksheet 15.2: Setting up a logbook (doc-12838)

15.4 Designing your investigation

15.4.1 One or more experiments

Once you have decided on a question to investigate, the next step is to design your investigation. Some questions will require you to carry out one experiment. More complex investigations may require a number of experiments. Each experiment needs to have an aim and a hypothesis. To ensure that your results and conclusions are valid your experiments must be carefully designed, variables must be identified and controlled as appropriate, and the experiment should be repeated to ensure the reliability of the data.

In a valid experiment only one factor or variable should be deliberately changed. So if your question cannot be answered by carrying out such an experiment, more than one experiment may be needed.

Joshua wants to investigate whether his family farm is polluting the local stream. He can answer this question by carrying out an experiment which will involve testing the stream water at various locations, including some locations upstream and downstream from the farm. The variable he is changing is the place from which the water is collected. Everything else, including the tests carried out, will be kept constant. He will carry out a number of tests on the water, but he is still doing one experiment. Jasmina on the other hand is interested in finding out how to grow the largest possible pumpkins. She will investigate the effect of adding different amounts of fertiliser, temperature and amount of water. Each of these three variables will require a different experiment. She is going to do all three experiments at the same time, but she needs to isolate the three variables to make valid conclusions.

Jasmina is interested in finding out how to grow really large pumpkins.

15.4.2 Aim and hypothesis

Each experiment should have an aim. An aim is a statement that starts with the word 'to' and states the purposes of the investigation. Jessica is investigating which biofuel releases the most energy per gram when burned. Her aim is 'to compare the heat of combustion of a range of biofuels'. Simon wants to find out whether the claim that 'drink X contains three times the vitamin content of orange juice' is correct. His aim is 'to measure the vitamin C content of drink X and different types of orange juice'.

A hypothesis is a statement that explains a set of observations and can be tested by a scientific investigation. A sensible hypothesis is based on observations and prior research. Joseph is planning to grow radish seedlings. Some of the seedlings will be kept in a dark cupboard and some seedlings will be exposed to light for a set number of hours per day. He has done some background reading and expects that the seedlings that are exposed to light around the clock will grow fastest. His hypothesis is 'increasing the number of hours of daily light exposure increases the growth rate of radish seedlings'. Joseph's experiment may or may not support this hypothesis.

A hypothesis can be tested through a scientific investigation. 'Girls are better at ice skating than boys' is not a suitable hypothesis because 'better' is not something that can be measured scientifically. 'Girls have fewer falls over a two hour session of ice skating than boys' could be tested scientifically. You could collect data about the number of male and female ice skaters at an ice rink, the number of falls and whether the person who fell was male or female. This could be repeated over a number of ice skating sessions and the hypothesis could thus be tested.

15.4.3 Valid experiments

A valid experiment measures what it actually sets out to measure. If your aim was to find out whether watering plants with sea water affects their growth rate, comparing the number of radish seeds that germinate after one week when watered with tap water or sea water would not be a valid method because it does not actually measure growth rate. It tests the effect of sea water on seed germination.

Controlling variables

In a valid experiment it is important to control variables. A **variable** is an observation or measurement that can change during an experiment. You should change only one variable at a time in an experiment. The variable you deliberately change during an experiment is called the **independent variable**. The variable that you are measuring (which is being affected by the independent variable) is called the **dependent variable**. For example, if you were performing an experiment to find out which brand of fertiliser was best for growing a particular plant, the independent variable would be the brand of fertiliser. The dependent variable would be the increase in height of the plants after a chosen number of days.

When you are testing the effect of an independent variable on a dependent variable, all other variables should be kept constant. Such variables are called **controlled variables**. In the fertiliser experiment, the type of plant, amount of water provided to each plant, soil type, amount of light, temperature and pot size are all controlled variables. The process of controlling variables is also known as fair testing.

The need for a control

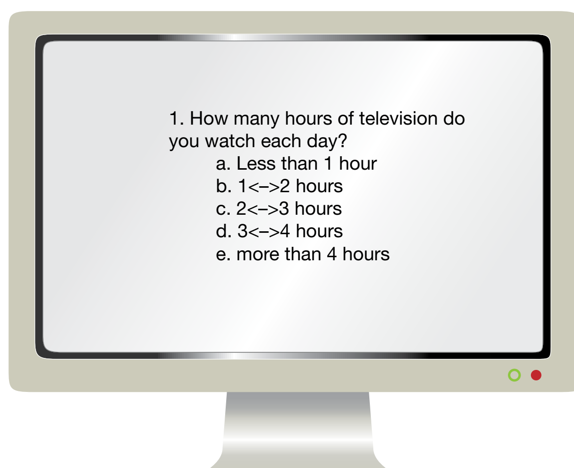
Some experiments require a **control**. A control is needed in the fertiliser experiment to ensure that the result is due to the fertilisers and not something else. The control in this experiment would be a pot of plants to which no fertiliser was added. All other variables would be the same as for the other three pots.

Reliable experiments

A reliable experiment provides consistent results when repeated, even if it is repeated on different days and under slightly different conditions; for example, in a different room or with a different researcher collecting the data. Replication increases the reliability of an experiment. This can involve simply doing the same experiment a few times, or having different groups repeat the same experiment and pooling the data gathered by each group when writing the report.

In experiments involving plants and in some medical research it is more practical to do the experiment once but use a large number of plants or research subjects. To test the effectiveness of a drug the same drug is given to a large number of people and the effects are monitored. In the case of the fertiliser experiment, a more reliable result could be obtained by setting up two, three or four pots for each brand of fertiliser, or having a number of seedlings in each pot. The results are checked for consistency and an average result for each brand or the control could then be calculated.

15.4.4 Surveys



A survey is a list of questions that you ask to a large group of people. Some surveys are read out, sometimes over the phone. Some require participants to fill in a form and increasingly surveys are done online. Surveys are used to collect census data, for market research, to find out what product characteristics consumers find most appealing, to determine voting intentions and also for scientific purposes. A great deal of data about health and lifestyle has been gathered through the use of surveys, sometimes in combination with other tests. To investigate whether there is a link between diet and blood pressure researchers might collect data about the participant's diet through the use of a survey. Below are some features of well-designed surveys:

- A large sample size is used — many participants take part in the survey.
- Questions are unambiguous — participants can understand the questions.
- A control group is used or, where appropriate, different degrees of exposure to the factor under investigation. An investigation on the impact of loud music on hearing could include a survey where participants were asked about the number of concerts and dance parties they attended over the last 12 months and the participants' hearing could be tested. The data would be of little value if all the participants had a similar level of exposure to loud music. The participants need to be people who are exposed to loud music frequently, some occasionally and some rarely.
- Data can be analysed mathematically. Multiple choice or short answer questions often lend themselves better to this type of analysis.

INVESTIGATION 15.2

Gooey liquid races

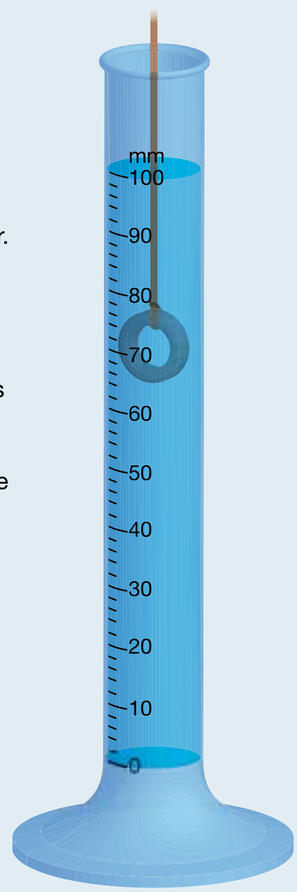
AIM: To compare the time taken for objects to fall through a range of liquids

You will need:

100 mL cylinder
a range of viscous clear liquids (e.g. detergent, shampoo, wallpaper paste, honey, oil, glycerine)
plasticine
cotton thread
marble
other small objects (e.g. washers)
stopwatch

- Collect one of the viscous liquids and fill a measuring cylinder to the 100 mL mark with the liquid.
- Attach a piece of cotton thread to one of the small objects.
- Drop the object into the liquid, keeping hold of the thread loosely so the object is not slowed down as it falls slowly to the bottom of the liquid. Use the stopwatch to measure the amount of time taken for the object to reach the bottom of the cylinder. The thread can be used to retrieve the small object from the liquid.
- Repeat the above step a further two times and calculate the average sinking time.
- To avoid waste and mess, keep the liquid in the measuring cylinder after use and pass it on to another group that might need it. At the very end of the experiment the liquids can be poured back into bottles so they can be reused the next time this experiment is done.

The basic experiment



Design your own experiment

1. Make a list of the variables that can affect the time taken for the object to reach the bottom of the measuring cylinder.
2. Choose one of the variables you listed in question 1 and design an experiment to test the impact of this variable on the sinking time. You should include the following:
   (a) the independent variable
   (b) the dependent variable
   (c) a table that lists at least three variables that need to be controlled and how you will control each
   (d) an aim
   (e) a hypothesis
   (f) a method written as a list of steps.
3. Ask your teacher to check your method, then carry out your experiment.
4. Tabulate your results.

15.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the following terms: 'independent variable', 'dependent variable', 'controlled variables', 'control', 'replication', 'hypothesis', 'sample size', 'survey'.
2. **Explain** why well designed plant experiments involve a large number of plants.

Think

3. For each problem below **identify** the independent and dependent variable and three variables that would need to be controlled.
   (a) Jossie wanted to find out if the water in her drink bottle would stay cold longer if she wrapped her drink bottle in foil or a towel.
   (b) Charlotte would like to know if ice blocks made from green coloured water melt at the same temperature as uncoloured ice blocks.
   (c) Jayden is testing the hypothesis that tall people are faster long distance runners than short people.
   (d) Shinji is testing the myth that plants grow faster if you play them music for at least two hours a day.
   (e) Nikita has heard that most people shrink slightly (in height) throughout the day and stretch out at night. She would like to know if this is true.
4. **Design** experiments to test each of the following hypotheses:
   (a) The waste water from the washing machine is suitable to water plants.
   (b) Bean plants will grow faster under red light than green light.
   (c) Ants are more attracted to sweet foods than cooked meat.
   (d) Freezing CDs for 24 hours before playing them for the first time improves their sound quality.
   (e) Paper towel A is more absorbent than paper towel B.
5. Use survey monkey or similar to design an online survey to test one of the following hypotheses, or another hypothesis of your choice (with your teacher's approval):
   (a) High school students spend more time using social media and less time watching television than their parents' generation.
   (b) Students who play competitive sport eat more serves of fruit and vegetables per day than students who do not play competitive sport.
   (c) Students who scored an A in Science last semester get more hours of sleep a night on average than students who scored other grades.

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Complete this digital doc: Worksheet 15.3: Variables and controls (doc-12839)

15.5 Gathering and presenting first-hand data

15.5.1 Is it precise?

As you plan and carry out your investigation you need to ensure that the data you collect is precise and accurate. Choosing the most appropriate instruments to make your measurements is important. Your teacher will probably ask you to collect evidence of your practical work. This may include photos and videos. You will then need to decide on the most appropriate way of presenting your results.

Choosing the correct piece of equipment is critical to ensure that your results are precise. Your bathroom scales and the electronic scales in a Chemistry laboratory both measure mass, but the laboratory scales are more precise. Your school might have different sets of scales that measure to one or two decimal places. Scales that measure to two decimal places are more precise. High precision scales are needed for some of the senior Chemistry experiments.

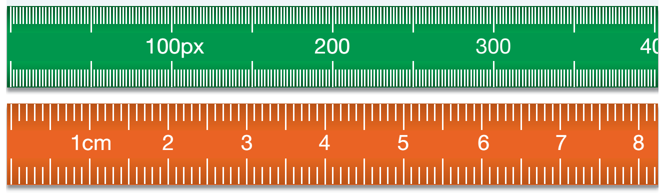
For measuring instruments with a scale, such as thermometers, rulers and measuring cylinders, the gradations (lines) on the scale give an indication of the precision of the instrument. Generally an instrument with smaller gradations is more precise, so of the rulers in the diagram below, the ruler on the top is more precise than the ruler on the bottom.

Precision scales

15.5.2 Is it accurate?

Measurements can be very precise, but incorrect. Every so often current affair programs bring attention to service stations that overcharge cos-tumers for petrol by having faulty petrol pumps that give inaccurate readings of the amount of petrol delivered by the pump. For each litre of petrol pumped the machine might give a reading of 1.1L and the customer is charged accordingly. The machine is quite precise, but not accurate.

Which ruler is most precise?



Some measuring instruments require calibration to ensure that they provide accurate measurements. The calibration might be part of the manufacturing process, or it may need to be carried out by the user regularly. A pH meter is a device that needs to be calibrated regularly. pH is a measure of the acidity of a substance. You can measure pH with a universal indicator. For a more precise reading a pH meter can be used. It is a device that is placed in the solution and it gives a reading of the pH to one or two decimal places. Over time it can lose its calibration and give inaccurate readings. A reading of 6.25 might be displayed when the solution actually has a pH of 5.38. To calibrate the pH meter you place it in solutions of known pH and adjust the device until it reads the correct values for these solutions.

A pH meter needs to be calibrated regularly to ensure it gives accurate readings.

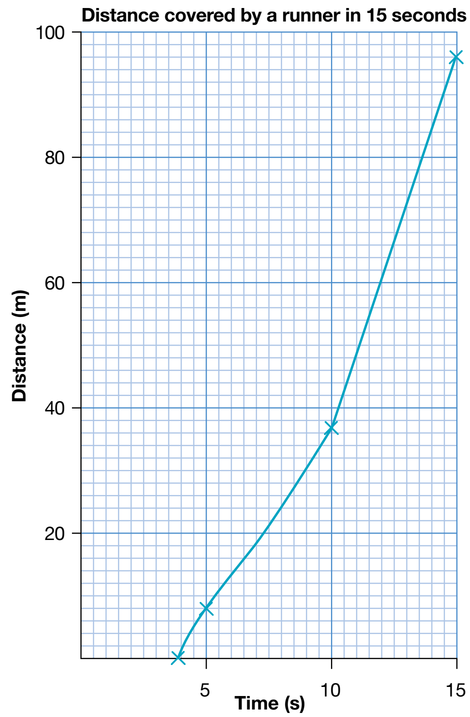
15.5.3 Qualitative or quantitative?

Qualitative data is not numerical. Combining hydrochloric acid with magnesium results in the formation of hydrogen gas. A qualitative observation might be that a gas was formed and a pop sound was heard when a lit match was placed in a sample of gas collected. Quantitative data involves numbers. ‘70 mL of gas was produced’ is a quantitative observation. In your SRP your teacher will probably expect you to collect quantitative data.

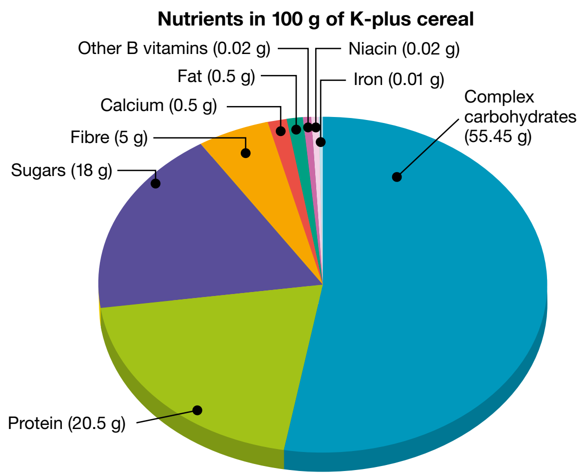
15.5.4 Presenting your data

Diagrams, photos and videos can be an effective way of providing evidence of your practical work and may form part of the results of your investigation. Analysing your results and identifying trends in your data will usually involve presenting some of your results in the form of tables and graphs. It is important to use the correct type of graph for your data.

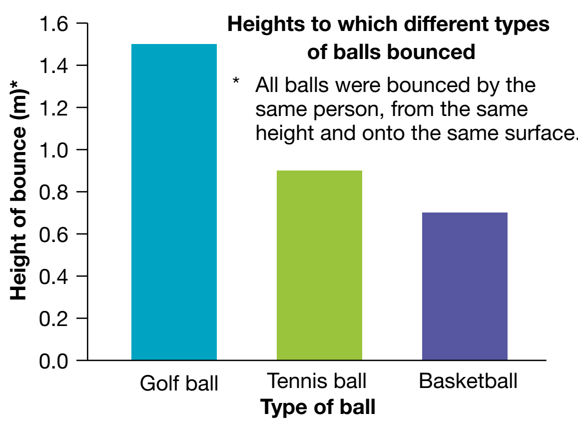
<table>
<tr><th>Type of graph</th><th>Applications</th><th>Example</th></tr>
<tr><td>Line graph</td><td>To present continuous data to show how the dependent variable (on the y-axis) changes as the dependent variable (on the x-axis) changes</td><td>



</td></tr>
<tr><td>Pie chart and divided bar graph</td><td>To show the proportions or parts that make up a whole</td><td>

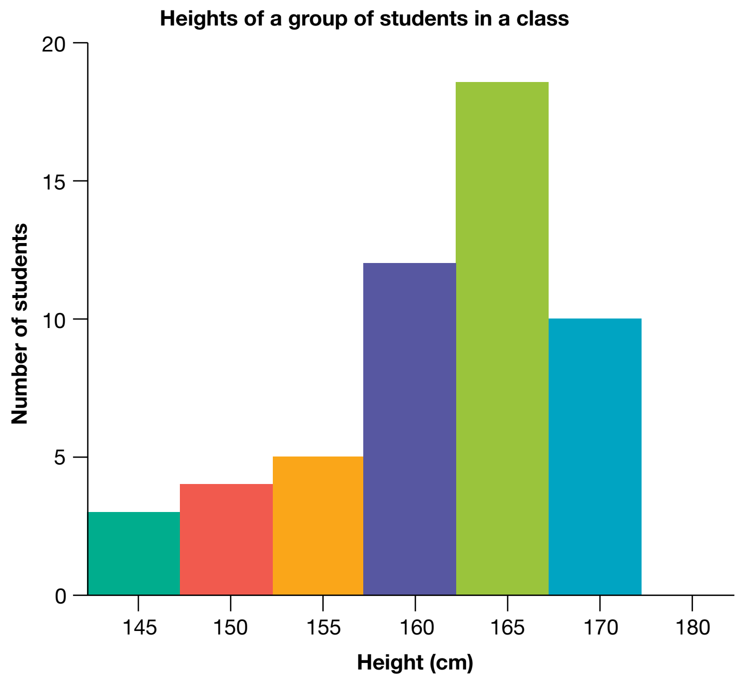


</td></tr>
<tr><td>Column graph</td><td>To present data that is not continuous and cannot be connected</td><td>



</td></tr>
</table>

Experiment results can be presented in a variety of ways.

<table>
<tr><th>Type of graph</th><th>Applications</th><th>Example</th></tr>
<tr><td>Histogram</td><td>Similar to column graphs except that the columns touch each other because the data is continuous</td><td>
</td></tr>
</table>

Tang is powder that can be added to water to produce an orange drink. The intensity of the orange colour gives an indication of the concentration of Tang. To estimate the concentration based on colour, you need to have some way of calibrating your observations. In this activity you will be preparing Tang drinks of known concentration, then using these to estimate the concentration of two drinks of unknown concentration.

INVESTIGATION 15.3

What does calibration involve?

AIM: To practise using data loggers

You will need:

Tang orange drink or similar (any coloured drink additive powder is suitable for this experiment. Schools that own a colorimeter may wish to do this experiment using a coloured salt rather a drink additive to avoid leaving a sticky residue on the colorimeter).
7 identical beakers
two jugs of pre-prepared Tang drink of unknown concentration
(optional) colorimeter

- Add 100 mL water to five of the beakers.
- Add Tang powder to each cup; accurately measure the amounts shown below.

Beaker number	1	2	3	4	5
Mass of Tang powder (g)	2	4	6	8	10

- Line up the beakers on the desk in order from least to most dilute. These are the standards.
- Pour 100 mL of the drinks of unknown concentration in two separate beakers. Estimate the mass of Tang dissolved in each beaker of drink by comparing the intensity of the orange colour to the standards.

Discussion

1. A colorimeter is a device that measures the intensity of the colour of a solution. It does this by shining a particular wavelength through the solution and measuring how much light it absorbs. Tang is orange, so it reflects orange light and absorbs mainly blue light. Concentrated Tang is more orange, so it absorbs more blue light than dilute Tang. If your school owns a colorimeter you could use it to measure the absorbance of the standards you prepared and the drinks of unknown concentration. Otherwise, use the results below. The absorbance readings have no meaning unless a calibration curve is produced. Use your own results or the sample results below to produce a calibration curve, which is a graph that shows concentration on the *x*-axis and absorbance on the *y*-axis. The standard solutions are plotted on the graph.

   Sample results

Mass of Tang added to 100 mL water (g)	Absorbance
2	0.15
4	0.30
6	0.45
8	0.60
10	0.75

2. The colorimeter is then used to measure the absorbance of the two orange drinks of unknown concentration. The results are shown at right.
   What is the concentration of drinks A and B? (Express your answer in terms of the mass of Tang dissolved in 100 mL of water.)

Drink	Absorbance
A	0.25
B	0.50

3. Explain why it was necessary to construct a calibration curve.

15.5 Exercise: Remember and think

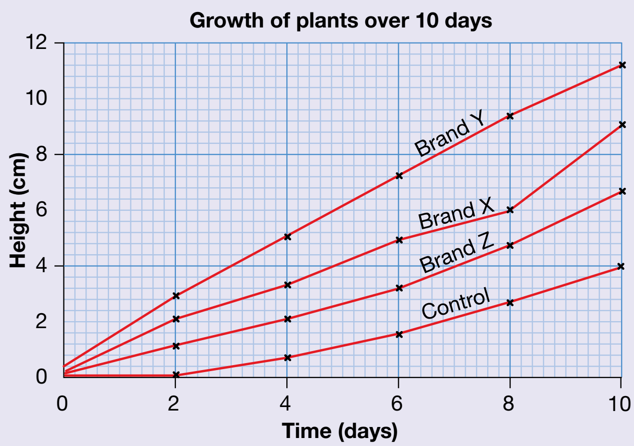
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

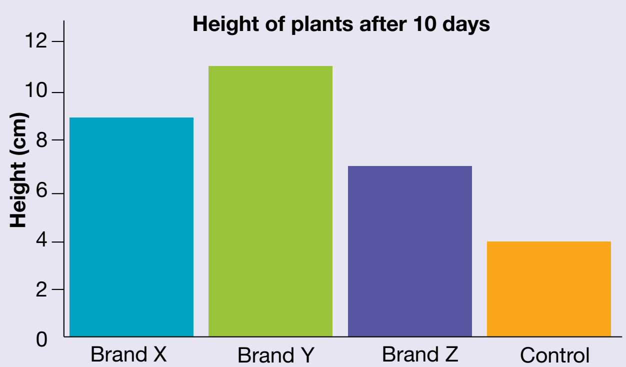
Remember

1. **Distinguish** between precision and accuracy.
2. **Outline** what calibrating an instrument involves.
3. **Explain** the difference between qualitative and quantitative data.
4. **Distinguish** between a column graph and a histograph.

Think

5. The two graphs at right show data from the same investigation. The student was investigating the effect of different brands of fertiliser on the growth of plants.
   (a) Write an aim for the experiment.
   (b) Which graph shows more information? Explain your answer.





(c) **Identify** two problems with the second graph.
(d) Write a conclusion for the experiment.

6. **Identify** the type of graph that would be most appropriate to display the following data:
   (a) data from Taronga Zoo showing how the mass of baby elephant Luk Chai has increased over time
   (b) the mass of each elephant at Taronga Zoo
   (c) the proportion of visitors using various modes of transport to travel to Taronga Zoo
   (d) the ratio of cordial to water in a drink
   (e) the amount of milk absorbed by different brands of breakfast wheat bars
   (f) the relationship between the concentration of salt in a sample of water and its boiling point.

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Complete this digital doc: Worksheet 15.4: Analysing results for a projectile investigation (doc-12840)

15.6 Using technology: data loggers and data collection probes

15.6.1 Collecting numerical data

Some probes can connect to a computer via a simple connecting device without the need for a separate data logger.

Your student research project might provide you with the opportunity to use a data logger to carry out your investigations. A data logger is a device that can collect and record many measurements very quickly. It can also be used to collect data more slowly over a long period of time. Various sensors can be plugged into the data logger. The sensors can measure temperature, pH, light intensity, mass, oxygen concentration and a whole range of other parameters. Some data loggers have a small screen and function like mini-computers. They can display the data collected in the form of a table or graph, and calculations on the data can be carried out directly from the data loggers. More basic data loggers simply collect and store the data, then they need to be connected to a computer so that the data can be downloaded to the computer. Software installed on the computer is then used to produce graphs and analyse the results. There are also probes that can connect into the USB port of a computer with a simple connecting device, so that a separate data logger is not actually required.

INVESTIGATION 15.4

Using a data logger and probe

You will need:

data logger
pH probe
ammonium chloride salt
dropper bottle of dilute sodium hydroxide (*)
temperature probe
magnesium ribbon
dilute hydrochloric acid (*)
(*) a solution of 0.5 mol/L is suitable for this experiment.

- Safety glasses must be worn for this investigation.
- Do not handle any chemicals with your fingers. Use a spatula to handle salts.
- Connect a temperature probe and a pH probe to your data logger or computer and set up the data logger or computer to collect data every second for 3 minutes (180 seconds).
- Place 25 mL hydrochloric acid in a 50 mL beaker.
- Lower the probes into the acid. You may need to use a retort stand and clamp to hold the beaker in place to ensure it does not tip over.
- Using a dropper gradually add 50 mL of the sodium hydroxide solution. Try to add the solution evenly over the full 3 minutes if you can.
- Save the results from this part of the experiment.
- Repeat all the steps above but instead of combining acid and sodium hydroxide combine the following:
  – Place 50 mL water in the beaker and add one spoon of ammonium chloride salt.
  – Place 50 mL acid in the beaker and a add small piece of magnesium ribbon.

Discussion

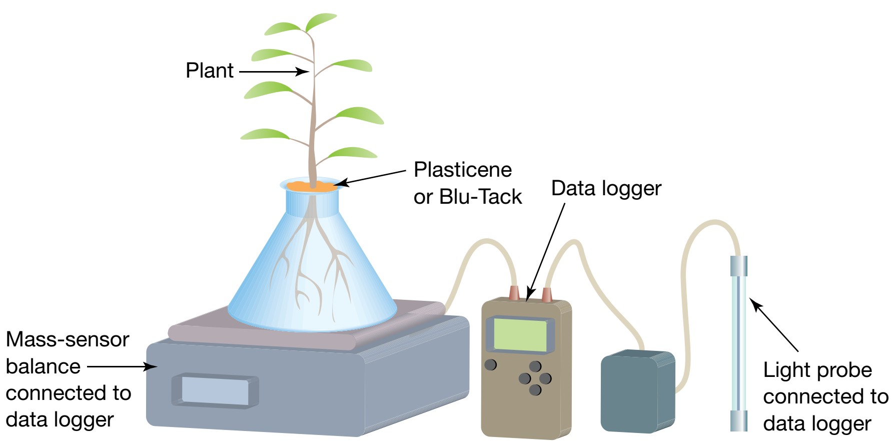
1. Copy and complete the following aim into your notebook:
   'To investigate how __________ and __________ change over time in three different chemical reactions'.
2. Print the graphs produced for each part of the experiment. If you are using a computer to write your report, you can cut and paste the graphs directly into the results section of your report.
3. Exothermic processes give off heat whereas endothermic processes take in heat. Identify the exothermic and endothermic processes.
4. Write a sentence to describe the change in pH for each reaction.
5. This experiment could be done with a thermometer and universal indicator or a pH meter instead of a data logger. List some advantages and disadvantages of using a data logger in this instance.
6. In this experiment what was:
   (a) the independent variable
   (b) the dependent variable?

15.6.2 What are the advantages of data loggers and data collection probes?

A data logger is particularly useful if you need to take many measurements very quickly. Recording the temperature of a solution every 0.1 seconds for 3 minutes would be an impossible task for a human, but not for a data logger. As the data is automatically recorded, there is also no need to frantically write down numbers.

This is important when values change rapidly. If you wanted to measure the amount of heat released when caustic soda dissolves in water you would need to dissolve some caustic soda in a certain amount of water and record the maximum temperature reached. This might be difficult to detect using a thermometer — you could miss the maximum temperature before it begins to fall again. With a data logger it is possible to plot the change in temperature and easily identify the maximum temperature reached by looking for the highest point on the graph.

The plant is sitting on a scale connected to the data logger. The mass of the plant is collected every hour for a week. The light sensor measures light intensity and the data from this sensor is also collected every hour and stored by the data logger.



Sometimes an experiment runs over a number of hours or days and measurements need to be collected regularly, even at night. If you wanted to investigate the effect of light intensity on the growth of a plant you could set up the experiment shown on the previous page. You could then use the data logger to record the light intensity and mass of the plant every hour for a week, and the experiment could run without the need for anyone to come into the lab to take any readings.

15.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

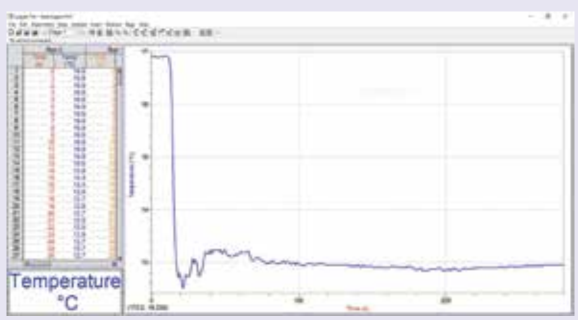
Remember

1. **Describe** a data logger in a way that a year 7 student would understand.
2. Match each of the words listed below with their meaning:

Word	Meaning
(a) Sensor	(i) You may need to download the data from the data logger to one of these
(b) Data logger	(ii) Piece of information
(c) Computer	(iii) These are plugged into the data logger and they take the measurements
(d) Data logger software	(iv) Allows you to input data into the data logger or computer by touching it with your finger or a stylus
(e) Touch screen	(v) Software that allows you to process the data collected by the data logger
(f) Data	(vi) A device that can collect and store data from sensors connected to it

Think

3. Extract the answers to the following questions from the figure below left.
   (a) Estimate at what time the pH was approximately 5.
   (b) Approximately when was the maximum temperature reached?
   (c) What was the pH and temperature after 180 seconds?



4. The graph above shows the change in temperature after 20 g of salt X was added to 100 mL water. Extract the answers to the following questions from the graph.
   (a) What was the temperature of the water at the start of the experiment?
   (b) What was the lowest temperature that the solution of salt X and water solution reached? How long after first adding the salt X crystals did this occur?

(c) Is dissolving salt X in water an exothermic or endothermic process? How do you know?
(d) Suggest why the line is not a smooth line. What might have caused the sharp drops in temperature?

5. Sensors are the devices that take the measurements that the data logger collects. **Outline** scientific investigations that could use data collected by sensors that measure:
(a) electric current
(b) acidity of solutions
(c) concentration of carbon dioxide in the air
(d) total dissolved solids (salt content)
(e) light intensity.
6. Ethan wanted to find out if sand heats up faster than water in the sun. He filled one beaker with sand and another with water. He placed a temperature probe connected to a data logger in each beaker and placed the two beakers in a sunny area of the playground. Half an hour later Ethan came back to collect the beakers, probes and data logger. Once back in the lab he downloaded the results to his computer and analysed the results.
(a) **Describe** another way this experiment could be done if you did not have access to a data logger.
(b) What are the advantages of using temperature and a data logger for this experiment?
(c) List some variables that should be controlled to ensure this is a fair test.
(d) When all the groups had finished the experiment, Ethan's teacher asked a student from each group to write the increase in temperature for each beaker on the board. Why is it a good idea to collect data from all groups?

Investigate

7. Acids are corrosive substances; they react with most metals, such as the magnesium in part 1 of the experiment in investigation 15.4. The temperature probe is made of metal but it doesn't react with acids. What sort of metal is it and what protects it from the acid?

15.7 Using technology: spreadsheets and databases

15.7.1 Spreadsheet or database?

A good SRP involves the collection of large amounts of data that need to be processed and analysed. You may need to use graphs to present your results and carry out complex calculations. Using a spreadsheet or database program can save you time when analysing your data and help you produce professional looking graphics.

The main reasons for using a spreadsheet program such as Excel are to make calculations faster, reduce the potential for calculation errors and produce high quality graphs quickly and easily. If your teacher had to add up all the marks for each student in your class using a calculator it would take a very long time. It would also be very easy to accidentally type the wrong number into the calculator. With a spreadsheet the same task can be done a lot more quickly and efficiently.

A database allows you to do most of the things you can do with a spreadsheet: you can carry out calculations and create graphs, for example. A database has the added advantage that it allows the user more flexibility when searching for data that matches particular criteria. For this reason a database is preferable if there is a large amount of data that will need to be searched. Also, the use of forms makes it possible for users to enter and retrieve certain data from the database without seeing all the data. This is important for sensitive data such as health information. Most large databases have different levels of permission and users have access only to the information they need.

Note: Basic Excel and Access skills were covered in stage 4. In the activities below instructions are provided for Excel and Access. Depending on the version of the software you are using, the exact methods may vary slightly from these instructions.

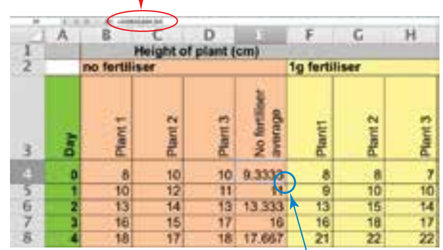
15.7.2 Using spreadsheets to process data

In your stage 5 SRP you may want to use a spreadsheet program to carry out calculations on the data you collect. Below are some tips for entering formulas into spreadsheets:

- A formula always starts with =
- The following symbols are used for mathematical operations:
  + for addition
  – for subtraction
  * for multiplication
  / for division.
- You can save time and avoid errors when writing formulas by using functions. A function is a short cut for a particular formula. For example, if you wanted to add cells A1 to A6 you could type in the formula =A1+A2+A3+A4+A5+A6 or simply =sum(A1:A6).
  The table below shows some commonly used functions.

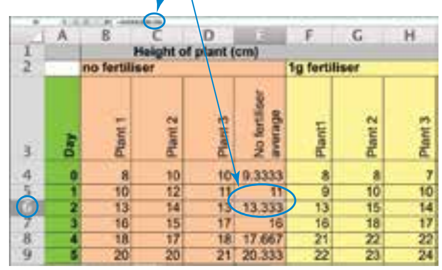
A formula can be copied to the cells in the same column or row by 'filling down'. In Excel that means dragging the little cross in the corner of the active cell down or across to the cells where the formula needs to be copied. When you do this, cell references in the formula will automatically adjust to match the row or column in which the copied formula ends up.

This is the formula that was typed in cell E4 to calculate the average of cells B4:D4.



Dragging this handle down the column copies the formula down the column.

Note that the cell coordinates have automatically adjusted to match the row number.



Common spreadsheet functions

Name	Application	Example	Result
AVERAGE	Calculates the average of the argument values	=AVERAGE(1,2,3,4)	2.5
COUNT	Counts the number of values in the argument	=COUNT(A3:A6)	4
MAX	Returns the largest value in the argument	=MAX(1,9,5)	9
MIN	Returns the smallest value in the argument	=MIN(1,9,5)	1
MODE	Returns the most common value in the argument	=MODE(1,1,5,5,1)	1
ROUND	Rounds the argument to the number of decimal places specified	=ROUND(12.251)	12.3
SUM	Calculates the sum of the values in the argument	=SUM(1,9,5)	15

Spreadsheet software can also be used to graph data. In Excel graphs can be produced by clicking on the insert tab and choosing the appropriate type of graph.

15.7.3 Using a database to store data

In a database each record (row) has a number of fields (columns). Your school probably uses a database to store information about students. Each student is a record and has an ID number. Some of the fields might be: first name, last name, home phone number, mother's first name and last name, father's first name and last name, each parent's address, etc. The same database might also store information about your timetable, medical information, and your school grades and report comments. Most databases store huge amounts of data and allow users to search for data that meets particular criteria very quickly. The technical term for this is 'running a query'. A teacher planning an excursion might run a query to access all the medical information for the students attending the excursion. To enter data into the database a form is usually used. A form is a particular screen where the user types in the information. The enrolment secretary at your school probably types information about new students into a form.

15.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Using data

1. Follow the instructions below to **construct** a spreadsheet showing sample results for an investigation where a student tested the effect of temperature on the bounce height of squash balls.
   Note: These instructions are for Microsoft Office 2010.
   (a) Open a blank spreadsheet and enter the data below.
   (b) Enter the following formula in cell H3: =average(B3:G3).
   (c) Drag the fill down handle all the way down to cell H14. The averages should appear in column H.
   (d) Select columns A and H, click on the insert tab then 'scatter' and choose the option where the points are joined by a smooth line.
   (e) Add a title and axis labels by clicking on the 'layout' tab and selecting the appropriate icons.
   (f) Format your graph as you wish by clicking on the 'format' button and investigating the various options

Temperature (°C)							
10	35	33	34	35	33	32	
15	39	38	37	38	42	39	
20	42	42	41	40	39	38	
25	45	44	46	47	42	40	
30	48	47	49	50	46	47	
35	50	49	52	51	50	49	
40	55	55	54	56	57	52	
45	62	60	59	63	62	59	
50	66	65	70	55	62	79	
55	61	60	54	61	62	59	
60	55	54	53	50	49	56	
65	50	48	48	52	48	49	

2. The table at right shows the results of an experiment that tested the amount of time taken for eucalyptus oils and other substances (0.1 mL of each) to evaporate at a particular temperature. The experiment was done twice.
   (a) Enter the data into a spreadsheet.
   (b) Use the spreadsheet function to **calculate** the average time that each substance took to evaporate.
   (c) Present the data in the form of a column graph.

Substance	Time (s) Trial 1	Time (s) Trial 2
Methylated spirits	4.17	1.85
Turpentine	63.48	43.02
Water	54.42	57.05
Oil from *E. rossi*	195.92	191.23
Oil from *E. nortonii*	103.99	105.39

3. The table at right shows the distance travelled by Nicole at 3-second intervals during a 100-metre sprint. The data was recorded during the sprint by attaching a paper tape to Nicole's waist. As she ran, the tape was pulled through a timer that printed a dot every 3 seconds.
   (a) Enter the data into a spreadsheet. **Calculate** the average speed travelled in each 3-second interval by applying a formula to the first cell in the column, and then copying it down. Remember that average speed can be calculated by dividing the distance travelled by the time taken:

Time (s)	Distance travelled in time interval (m)	Average speed for time interval (m/s)
0	0	
3	35	
6	25	
9	15	
12	15	
15	10	

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

   (b) What was Nicole's average speed over the total time?
   (c) **Construct** a line graph showing time versus distance, then a separate line graph showing time versus Nicole's speed.
4. The data at right was collected by two car servicing centres in Canberra in 1998, at the request of a student. The table shows the level of carbon monoxide and carbon dioxide emissions (as a percentage of total emissions) from cars of various ages.
   (a) Enter the data into a spreadsheet and create a graph to display these results.
   (b) Create formulas to work out the average carbon monoxide and carbon dioxide emissions for:
      (i) cars manufactured up to 1985
      (ii) cars manufactured from 1987 onwards.
   (c) Car manufacturers were required to install catalytic converters in cars made after 1986. Catalytic converters cut down carbon monoxide emissions by converting some of the carbon monoxide to carbon dioxide. What can you conclude from these data about the success of catalytic converters?

Year car manufactured	Carbon monoxide (%)	Carbon dioxide (%)
1977	3.17	11.8
1983	2.48	13.6
1985	3.7	11.4
1987	1.6	13.1
1989	1.08	10.2
1996	0.19	15.2

5. For her SRP Jossie is making acid/base indicators using flowers and other plant parts. She would like to find out which flower colours make the best acid/base indicators. On the next page are the results she has collected so far.

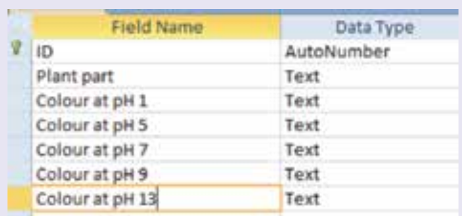
Plant part used	Colour at pH 1	Colour at pH 5	Colour at pH 7	Colour at pH 9	Colour at pH 13
Beetroot	Red	Red	Red	Red	Purple
Blackberries	Red	Red	Blue	Blue	Blue
Blueberries	Red	Blue	Blue	Blue	Blue
Cherries	Red	Red	Purple	Blue	Blue
Curry powder	Yellow	Yellow	Yellow	Red	Red
Geranium petals	Red	Red	Red	Blue	Blue
Petunia petals	Pink	Pink	Pink	Violet	Violet
Red cabbage	Red	Red	Purple	Green	Yellow
Rose petals	Red	Red	Pink	Blue	Blue
Purple peonies	Pink	Pink	Pink	Purple	Purple
Buttercup petals	Yellow	Yellow	Yellow	Yellow	Yellow

Use the instructions below to construct a database for Jossie's results.
Note: The instructions below are for Access 2010.

(a) Open Microsoft Access and create a blank database with the name 'plant indicators' and save where you normally save your Science work.

(b) Click on the *Design view* icon 

. You will be prompted to give the table a name. Table 1 is an appropriate name.



Field Name	Data Type
ID	AutoNumber
Plant part	Text
Colour at pH 1	Text
Colour at pH 5	Text
Colour at pH 7	Text
Colour at pH 9	Text
Colour at pH 13	Text

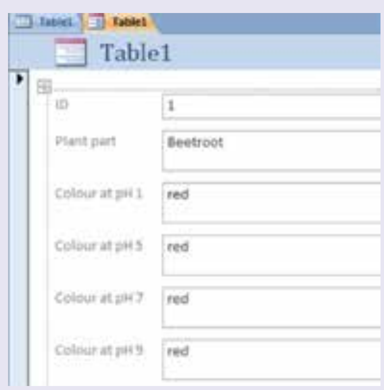
(c) Type in the fields shown in the screen clipping at right. As you type in the field names the data type will automatically be entered as text.

(d) In the next step we will be creating a lookup (or drop down) menu. This means that when we enter the data into the database we will be able to choose from a list of options for this field. Click on the word 'text' that appears to the right of the field name 'colour at pH 1'. Select 'lookup wizard' from the drop down menu. Work through the wizard choosing the following options as you go:
   (i) step 1: choose 'I will type the values that I want'.
   (ii) step 2: enter the following in column 1: Red, Pink, Yellow, Blue, Purple, Green
   (iii) step 3: Use the default label (colour at pH 1) and check the option 'limit to list', then click the 'finish' button.

(e) Work through the instructions in part (d) above to create look up wizards for the next 4 fields. Save the table.

(f) Click on the *Table view* icon 

. You will be prompted to save the table.



(g) You could now type the data into the table, but instead you will be creating a form to make it easier to enter data. Click on the *Create* tab and select *Form*. A form will automatically appear. The figure at right shows a section of the form. You can format it as you wish by clicking on the format tab. Use it to enter the data into the database. Click on the right-hand arrow to go to the next record.

(h) The real value of a database is that it allows you to search for data that matches particular criteria. You can do this by running a query. Click on the Create tab again but this time select the *Query wizard* and select *Simple Query wizard*.

(i) In the next dialogue box move ‘plant part’, ‘colour at pH 1’ and ‘colour at pH 9’ to the right-hand column by selecting each one and clicking on the right-hand arrow. Click on ‘next’.
(ii) Choose an appropriate heading.
(iii) On the next screen choose ‘modify the query design’.

(iv) Fill in the next table that appears as shown above right. Note that the inverted commas do not need to be typed in. They will appear automatically when you click on a different cell.

(i) Click on ‘run’ (red exclamation mark). A table showing all the indicators that are red at pH 1 and blue at pH 9 should be displayed.

(j) Modify steps (a)–(j) to design and run a query that will identify indicators that are yellow at pH 1.

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Complete this digital doc: Worksheet 15.5: Spreadsheeting and graphing (doc-12841)

Complete this digital doc: Worksheet 15.6: Calculating using a spreadsheet (doc-12842)

15.8 Writing your report

15.8.1 Your report

A report for an SRP follows an particular format. Below are some of the sections that are usually included in an SRP report, although you should check with your teacher to find out exactly what is required as your school may use a slightly different format. The left-hand side of the table describes the features of the different sections of the report. The right-hand side shows a partially completed example. You could work through the experiment described and complete the report to practise your scientific report writing skills.

Report section	Example
Heading • Write down the problem you are investigating as a question.	*Which flowers produce the best acid–base indicators? Can you predict whether a flower will make a suitable acid–base indicator from its colour?*
Abstract • Write this last. • An abstract gives an overview of the project. The abstract allows the reader to decide whether the research paper will be useful to them. • In scientific journals, abstracts are usually written in the past tense and in the passive voice; i.e. rather than writing ‘I poured 50 mL water into a beaker’ you should write ‘50 mL of water was poured into a beaker’.	This abstract may not match your results. Modify it to match the data you obtain when you do this experiment. *The purpose of this experiment was to find out whether there is a relationship between the colour of flowers and whether certain flowers are suitable to make acid–base indicators. A range of flowers of various colours were used to make indicators. The flowers were ground up with a small amount of methylated spirit to extract the pigment. The coloured extract was then added to solutions of various pH levels. The extract from most flowers except yellow flowers was a different colour in acid and alkalis, although the colour change did not occur at the same pH for all flowers tested. All the purple flowers tested were suitable for making indicators. Some of the purple flowers went through a number of colour changes as the pH was changed.*
Hypothesis • A testable statement that explains a set of observations	*Pigments extracted from purple and red flowers work as acid–base indicators whereas pigments extracted from yellow and white flowers do not.*

(*Continued*)

Report section	Example
Apparatus • A list of equipment used in the experiment	You should read the method below and write your own list of equipment.
Method • A list of steps that explain how to do the experiment • In scientific journals methods are written in the past tense and passive voice. At school, methods are sometimes written in the text type called ‘procedure’ and the present tense may be used. Check with your teacher how you should write your method.	1. *A range of flowers of various colours was collected.* 2. *The petals of each flower were removed and ground up with 20 mL methylated spirit in a mortar and pestle.* 3. *Small amounts of 1 mol/L hydrochloric acid, citric acid powder, water, baking soda and 1 mol/L sodium hydroxide were placed on a sheet of plastic (e.g. overhead projector sheet).* 4. *A few drops of the coloured extract obtained from each flower were added to each substance.* 5. *The colour of the indicator in each substance was recorded.* 6. *Universal indicator solution was used to measure the pH of the hydrochloric acid, citric acid, water, baking soda, and sodium hydroxide. Two drops of universal indicator solution were added to each substance and the colour produced was compared to the colour chart provided with the universal indicator solution.*
Results • Include your observations and measurements. • Where possible, present the results in a way that allows the reader to identify trends and patterns easily (e.g. as a table or graph).	A table with the headings shown below could be used to present the results for this experiment. You will also need another table to record the pH of the solutions tested.

Table 1: Colour of flower extracts in a range of substances

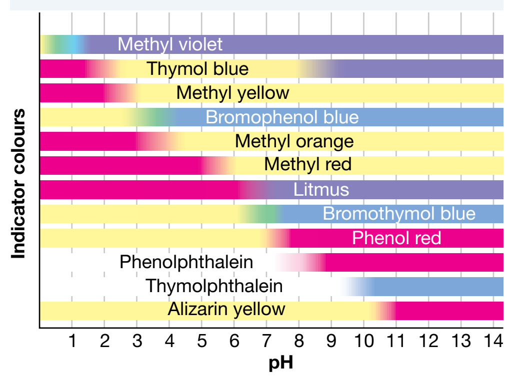
	Colour in each substance				
Flower used	**Hydrochloric acid**	**Citric acid**	**Water**	**Baking soda**	**Sodium hydroxide**

Table 2: pH of substances that were combined with the flower extracts

Substance	pH
Hydrochloric acid	
Citric acid	
Water	
Baking soda	
Sodium hydroxide	

The graph at right shows another way to present your results, although the names of the flowers you use should replace the names of the indicators.

Colours of common indicators at various pH levels



Report section	Example
Discussion In this section you should: • identify general trends in your results • explain how your results might be useful • identify sources of error • suggest improvements to your experiment • suggest further experiments that might be carried out in this field.	To complete this section write a paragraph that answers the questions below: 1. Can you identify any trends in your results (which colour flowers tended to work as indicators, which ones didn't work)? 2. Were there any problems or limitations with your method? For example: – Were you able to test a large number of flowers of each colour? – Did you follow exactly the same method to make the indicator each time? 3. How could your method be improved in terms of its validity, accuracy and reliability? *Note:* Remember that a valid experiment measures what it set out to measure and is a fair test with all the necessary variables controlled. In this instance the validity of the experiment could be improved by ensuring that the same weight of flower petals and the same amount of solution and powders were used for each flower. Reliability means that the same results will be obtained consistently if the experiment is repeated. For instance, an experiment where only two purple flowers were tested is not a reliable way to check whether most purple flowers make good acid–base indicators. Repeating the experiment and including many flowers of each colour would improve the reliability of the experiment. You should also discuss the accuracy and precision of the measurements. How could pH have been measured more accurately in this experiment? 4. Are there further experiments that could be done to gather more knowledge about this problem (e.g. obtain pure samples of the coloured chemicals found in flower petals and test whether they work as acid–base indicators)?
Conclusion • An overall statement that summarises the trends in your results and relates back to the aim • Your conclusion should state whether your results support your hypothesis.	Can you write your own?
References • A list of all the books, journal articles, websites etc. you used as a source of information for your SRP. There are a few different formats used for reference lists (also called bibliographies) so you should check the format required by your school. • You may also wish to have an acknowledgements section where you thank people who helped you.	The Harvard referencing format for books is as follows: Author(s), date of publication, title (*in italics if typed* or <u>underlined</u> if handwritten), publisher, city where published. So if you wanted to include the book you are reading now in a reference list you would write it as: Warnant, P, Arena, P, Burrows, K, Evergreen, M and Lofts, G 2018, *Core Science Stage 5 NSW Australian curriculum*, John Wiley and Sons, Milton.

15.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Think

1. **Explain** why it is best to write the abstract last.
2. **Explain** why the method you describe in your final report is often significantly different to the method you described in your SRP plan.
3. Write the following instructions in the past tense and passive voice. An example has been done for you.
   Example:
   Read the book. The book was read.
   (a) Chop up some flower petals.
   (b) Combine 20 mL hydrochloric acid with 40 mL sodium hydroxide.
   (c) Add three spoons of sugar to 100 mL water.
   (d) Measure the time taken to dissolve with a stopwatch.
   (e) Wrap some aluminium foil around a test tube.

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Complete this digital doc: Worksheet 15.7: Report modelling (doc-12843)

15.9 Sample SRP

15.9.1 Investigating muddy water

Sean, who is a Year 9 student, conducted an investigation to compare the turbidity (cloudiness) of water in the following three locations:

- a creek near his school
- a creek near his home
- a river near his home.

His search for information in the library revealed that the cloudiness was caused by particles of soil (and sometimes pollution) suspended in the water. Sean chose his topic because he was interested in the environment. He felt that clean water was the right of all living things. His research and background knowledge led him to form the hypothesis that 'the clearest water will be in the river'.

Sean took water samples from each of the three locations on four days. He found a method of measuring turbidity from a library book. It involved adding a chemical called potash alum to a sample of water in a jar. The potash alum makes the particles of suspended soil clump together and fall to the bottom of the jar. A layer of mud is formed. The height of the mud at the bottom is then measured.

A summary of Sean's method, including a list of materials and equipment required, is given below. You will notice that Sean used a fourth sample. It was needed as a control and contained distilled water. This was to ensure that there was nothing in the pure water to cause a layer at the bottom of the jar when the potash alum was added. His results are in the table on the next page.

Method:

- 4 large jars or bottles with lids for collecting water samples (capacity of about 1 L each)
- 4 identical jam jars with lids, labelled 1, 2, 3 and 4
- metal teaspoon (not plastic, in case it breaks)
- potash alum (potassium aluminium sulfate)
- 4 water samples from different locations
- ruler with 1-millimetre graduations

- 100 mL measuring cylinder
- permanent marker

1. Water samples (about 1 litre each) were collected from a specific part of the creeks and river on the same day.
2. Each of three clean jars was filled to the same level with the water samples — a labelled jar for each location. A fourth labelled jar was filled to the same level with distilled water.
3. One level teaspoon of potash alum was added to each jar. Lids were put on the jars and the jars were shaken.
4. The jars were left for 30 minutes to allow the particles to settle.
5. The height of the layer of mud on the bottom of each jar was measured and recorded.
6. The jars were emptied and washed and the experiment was repeated three more times.
7. Water samples were collected from the same locations on three other days over a ten-day period and the entire experiment was repeated three more times.

Results

Results table measuring the levels of mud in water samples from three areas

Water sample	Height of mud (mm)															
	Day 1				Day 2				Day 3				Day 4			
	Test				Test				Test				Test			
	1	2	3	Average	1	2	3	Average	1	2	3	Average	1	2	3	Average
1. Home cretek	3.5	4.0	5.0	4.2	5.0	4.5	5.0	4.8	4.5	5.0	4.5	4.3	5.0	4.5	4.0	4.5
2. School creek	2.5	2.0	2.0	2.2	3.0	2.5	2.5	2.7	2.0	2.5	2.5	2.3	2.0	2.0	2.5	2.2
3. Barnes River	1.0	0.5	0	0.5	2.0	1.0	1.5	1.5	0.5	1.0	0.5	0.7	0.5	0.5	0.5	0.5
4. Distilled water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

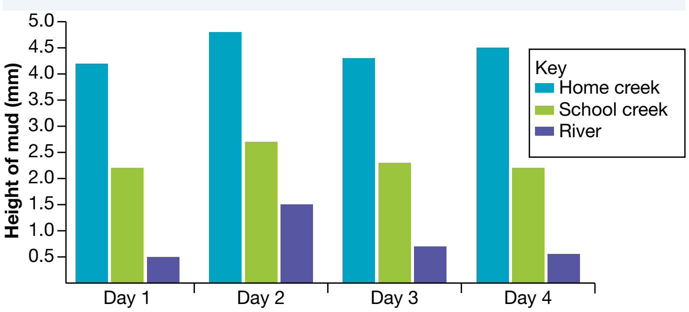
15.9.2 Analysing the data

Sometimes it is necessary to refine the 'raw data' (the data initially collected), presenting it in a different way. Sean was planning to use his average measurements to make a column graph. He decided to simplify his table so that it was easier to construct the column graph. The simplified table and column graph make it easier for others to read the results, and easier for Sean to see patterns and draw conclusions.

Table showing average heights of mud in water from three different areas

Sample number and source	Height of mud (mm)			
	Day 1	Day 2	Day 3	Day 4
1. Home creek	4.2	4.8	4.3	4.5
2. School creek	2.2	2.7	2.3	2.2
3. River	0.5	1.5	0.7	0.5

Sean's graph makes it easier to see patterns and draw conclusions.



15.9.3 Being critical

Sean was pleased with his results and was able to draw conclusions. In the discussion section of his report, he suggested that further studies be done. The turbidity was affected by weather conditions and the sampling needed to be done over a longer period, and in different weather conditions. Sean had recorded weather details on each day that he sampled water and was able to explain the very high mud level in the river on day 2. It is almost always possible to suggest improvements to an experiment.

15.9.4 Drawing conclusions

Sean's hypothesis, that the clearest water would be in the river, was supported. His conclusion was written in point form.

1. The home creek has the muddiest water, with sample values ranging from heights of 4.2 to 4.8 mm of mud per 200 mL of water. The school creek has moderate amounts of mud compared to the other two samples. Sample values ranged from 2.2 to 2.7 mm of mud per 200 mL of water. The river water is the clearest, with sample values of 0.5 to 1.5 mm of mud per 200 mL of water.
2. Weather conditions can alter the amount of mud in water bodies by either adding run-off from drains or stirring up the water. This was particularly noticeable in the samples taken from the river site on day 2, which followed a period of rain.

Chemical waste running into a river. How might you test for such materials in a water sample from this site?

Sean's teacher was pleased and suggested that Sean carry out further research and rewrite his material. And what did he think about entering his project for the Crest awards, or the BHP or Young Scientist competitions?

The last word comes from Sean. After successfully completing his student research project, he said: 'It all depends on the experimental design — get that right and the rest is likely to run smoothly.'

15.9 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Think

1. For Sean's experiment **identify**:
   (a) the independent variable
   (b) the dependent variable
   (c) the variables he controlled.
2. **Explain** why a sample of distilled water was included in Sean's experiment.
3. **Explain** why Sean repeated the experiment 3 times on 4 separate days.
4. Suggest how Sean could improve the reliability and accuracy of his experiment.
5. Why did Sean use a column graph rather than another type of graph to present his results?
6. **Explain** why it was a good idea to graph only the averages rather than graph all the data.
7. Suggest other tests Sean could have carried out on the water samples.
8. The turbidity of a creek usually increases after rain. **Explain** why.

15.10 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. Match the words in the list below with their meanings:

Words	Meanings
(a) Conclusion	(i) Concerns that deal with what is morally right or wrong
(b) Abstract	(ii) A document that lists the risks associated with an activity and the steps that must be taken to minimise these risks
(c) Discussion	(iii) The variable that is deliberately changed in an experiment
(d) Results	(iv) The part of a journal article where a brief overview of the article is given
(e) Hypothesis	(v) A list of steps to follow in an experiment
(f) Risk assessment	(vi) The answer to the aim or the problem
(e) Ethical considerations	(vii) A list of equipment needed for the experiment
(h) Independent variable	(viii) The variable that is measured in an experiment
(i) Dependent variable	(ix) States what was seen or measured during an experiment. May be presented in the form of a table or graph.
(j) Method	(x) Testable statement that explains a set of observations
(k) Apparatus	(xi) The part of a report where problems with the experiment and suggestions for improvements are discussed

2. **Outline** some of the information that needs to be included in the risk assessment for an experiment.
3. Give an example of a substance that would need to be labelled with each of the pictograms at right.

4. It has been proposed that adding iron sulfate to the oceans could reduce atmospheric carbon dioxide levels and thus bring global warming under control. The iron sulfate would promote the growth of algae. As algae carry out photosynthesis they take up carbon dioxide. Would it be ethical to test this idea by dumping large quantities of iron sulfate in all the world's oceans? **Justify** your answer.
5. Miranda wanted to test the following hypothesis: 'Hot soapy water washes out tomato sauce stains better than cold soapy water.'
   (a) List the equipment she will need.
   (b) **Identify** the independent and dependent variables in this investigation.
   (c) List five variables that will need to be controlled.
   (d) **Outline** a method that could be used to test the hypothesis.
   (e) Miranda's results are shown the table above right.
   (f) Write a conclusion based on Miranda's results.

Water temperature (°C)	Observations
40	Faint stain left after washing
60	No stain left after washing
80	No stain left after washing

6. Gemina and Habib wanted to investigate whether the type of surface affects how high a ball bounces. Habib thought the ball would probably bounce the highest off a concrete floor. They dropped tennis balls from different heights on a concrete floor, a wooden floor and carpet. Their results are shown in the table on the next page.
   (a) Write a hypothesis for this experiment.
   (b) **Construct** a line graph of Gemina and Habib's results.

(c) Use your graph to estimate the values X, Y and Z.
(d) List the equipment needed for this experiment.
(e) **Identify** two variables that had to be kept constant in this experiment.
(f) **Identify** two trends in the results.
(g) Do the results support the hypothesis you wrote?
(h) **Predict** how high the tennis ball would bounce off each floor if it was dropped from a height of 225 cm.

Distance ball dropped (cm)	Average height of bounce (cm)		
	Concrete	Wood	Carpet
25	22	14	8
50	46	34	18
75	70	50	26
100	94	66	34
125	X	85	Z
150	128	94	48
175	129	Y	50
200	130	100	51

Test yourself

1. In which part of a SRP report do you write a brief overview of the project?
   (A) Discussion
   (B) Introduction
   (C) Abstract
   (D) Method **(1 mark)**
2. In a valid experiment the variable that is deliberately changed is called the
   (A) independent variable.
   (B) dependent variable.
   (C) controlled variable.
   (D) fixed variable. **(1 mark)**
3. A scientist decided not to do an experiment because it may cause the test animals to experience pain. This is an example of
   (A) safety considerations.
   (B) economic considerations.
   (C) legal considerations.
   (D) ethical considerations. **(1 mark)**
4. Jossie used universal indicator to test the pH of a solution. To increase the accuracy of her measurement she could
   (A) use a pH meter rather than universal indicator to measure pH.
   (B) repeat the measurement 5 times and calculate the average reading.
   (C) ensure that she uses exactly 100 mL of solution.
   (D) use a sample of distilled water as a control. **(1 mark)**
5. Design an experiment to test the following hypothesis: 'lemon juice and vinegar can prevent sliced apple from turning brown'. Outline a suitable method and describe the observations that would be recorded. Construct a suitable table that could be used to enter the results. **(6 marks)**

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Complete this digital doc: Worksheet 15.8: Student research project and skills puzzle (doc-12844)

Complete this digital doc: Worksheet 15.9: Student research project and skills summary (doc-12845)

GLOSSARY

absolute zero: temperature at which the particles that make up an object or substance have no kinetic energy, approximately –273.15 °C
absorbed dose: the average amount of energy in Joules absorbed per kilogram of body mass
acceleration: rate of change in speed
accommodation: changing the lens shape to focus a sharp image on the retina
active (volcano): describes a volcano that has recently erupted and is likely to erupt again in the near future
active (wire): the wire that carries AC electricity to a house
activity: rate at which air particles around a radioactive substance become ionised
acute radiation syndrome: when a person is exposed to a high dose of radiation over a short period of time, such as minutes or hours
adenosine triphosphate (ATP): a compound containing adenosine and three phosphate molecules. It is present in all living organisms and provides energy for cellular reactions. The major supplies are produced in the mitochondria. It is a high-energy compound, enabling cells to perform work and providing the immediate source of energy for muscular contraction at the filament level.
air pollution: chemicals, particles, or biological materials that cause discomfort, disease, or death to living organisms
air pressure: the force created by air particles on an object
air resistance: the force of the air pushing back against an object moving through it
alkali metals: very reactive metals in Group I of the periodic table
alkaline earth metals: reactive metals in Group II of the periodic table
alleles: different forms of a gene for a particular characteristic. Each allele is characterised by a slightly different nucleotide sequence.
alpha rays: rays caused by alpha particles which are positively charged helium nuclei
alveoli: tiny air sacs in the lungs at the ends of the narrowest tubes. Oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide.
ammeter: device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.
amplitude: maximum distance that a particle moves away from its undisturbed position
angiosperms: flowering plants
anions: atoms or groups of atoms that have gained electrons and are negatively charged
anticlines: downward folds in rocks
antigen: substance that stimulates the production of antibodies
aqueous solution: liquid mixture in which the solute is dissolved in water
artificial selection: when humans mimic the process of natural selection by artificially selecting certain desired characteristics in a population in their breeding of domesticated plants and animals
asthenosphere: plates of the lithosphere which float on a layer of magma that can be up to 200 km thick
atmosphere: the layer of gases around the Earth
atom bombs (or A bombs): bombs which use uncontrolled chain reactions in unstable radioactive
atomic number: number of protons in the nucleus of an atom. The atomic number determines which element an atom is.
audio: waves with a frequency range of sounds audible to people
auditory nerve: a large nerve that sends signals to the brain from the hearing receptors in the cochlea
average speed: distance travelled divided by time taken
axon terminal: end of axon where it adjoins other neurons or an effector organ
axon: an appendage of the neuron that nervous impulses travel along to the next neuron or to an effector organ (muscle or gland)

background radiation: radiation from radioactive substances occurring naturally as part of the Earth's crust
Banksia: a plant native to Australia and New Guinea, with narrow leaves and cylindrical flowers
base station: consists of antennas on top of a large tower which transmit signals from mobile phones to a switching centre
beta rays: high-energy, high-speed electrons or positrons emitted by some types of radioactive nuclei
bile: a substance produced by the liver that helps digest fats and oils
biodiversity: the variety of species of biological organisms, often in relation to a particular area
biogeography: geographical distribution of species
bioluminescence: the release of light energy from a living thing
biomass: material produced by living organisms
biomes: regions of the Earth divided according to dominant vegetation type
biosphere: the life-support system of the Earth
biota: living things
black hole: the remains of a star, which forms when the force of gravity of a large neutron star is so great that not even light can escape
blue shift: shift of lines of a spectral pattern towards the blue end when a light source is moving rapidly towards the observer
body waves: P-waves and the S-waves that are both able to travel through the interior of the Earth
bonding electrons: shared electrons holding two atoms together
brachytherapy: cancer treatment also known as internal radiotherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.
brain stem: sometimes called the medulla. It is the part of the brain connected to the spinal cord and is responsible for breathing, heartbeat and digestion.
branching evolution: a population divided into two or more new populations that are prevented from interbreeding
capacitors: an apparatus for accumulating and holding an electrical charge, consisting of two conducting surfaces separated by an insulator; condensor
carrier waves: radio waves that are altered in a precise way so that they contain an audio signal
catalyst: chemical that starts to help or speed up a chemical reaction
cathode ray oscilloscope: a device that converts sound energy into electrical energy, allowing sound waves to be studied
cations: atoms or groups of atoms that have lost electrons and are positively charged
cell: the smallest unit of living things
cell body: contains the nucleus of a neuron, also called grey matter
cell phones: mobile phones, so called because base stations that receive mobile phone transmissions are arranged in a network of hexagonal cells
cellular respiration: the chemical reaction involving oxygen that moves the energy in glucose into the compound ATP. The body is able to use the energy contained in ATP.
cellular system: mobile phone system
central nervous system (CNS): made up of the brain and spinal cord and is necessary for thought processes
central volcanoes: any phenomena associated with volcanic activity, both past and present, that are not lava fields
cerebellum: found between the cerebrum and the brain stem, it is the part of the brain that controls balance and muscle action
cerebral fluid: fluid surrounding the brain
cerebrum: made up of two hemispheres, it is the largest part of the brain
chain reaction: a nuclear reaction where neutrons released in this process then go on to cause the splitting of other uranium-235 nuclei, which produces more neutrons

chemical barriers: body fluids that help prevent pathogens from entering the body
chemical bond (or molecular bond): the link that holds the atoms together in a substance
chemical formula: shorthand statement of the elements in a substance showing the relative number of atoms of each kind of element
chemiluminescence: light produced from a chemical reaction
chips: tiny pieces of silicon onto which tiny electric circuits can be etched
chlorofluorocarbons (CFCs): organic compounds used as coolant agents, propellants in aerosols and solvents. Their manufacture is being phased out as they also cause damage to the ozone layer.
chromosomes: a structure found in the nucleus of most cells, carrying genetic information
ciliary muscles: muscles that control the shape of the lens behind the iris
circuit breaker: safety device that breaks a circuit if the current suddenly exceeds a specified size. Circuit breakers can be reset.
climate sensitivity: the measure of temperature change in the climate, dependent on the amount of carbon dioxide released into the atmosphere
coaxial cables: wires that transmit a number of different signals as electrical pulses
cochlea: the snail-shaped part of the inner ear. It is lined with tiny hairs that are vibrated by sound and stimulate the hearing receptors.
coevolved: two species whose evolution has been influenced by selective pressures exerted on each other, e.g. bees and the flowers they pollinate
cold fusion: in cold nuclear fusion, two small nuclei combine to form larger nuclei, releasing energy at low temperatures
combination reaction: chemical reaction in which two substances, usually elements, combine to form a compound
combustion reactions: chemical reactions in which a substance reacts with oxygen and heat is released
common ancestor: an ancestral species common to all organisms
commutator: device attached to the rotor shaft that receives the current. In most motors it is a metal ring split into sections.
competition: the striving for the use of common resources between or within species; two groups of organisms are in competition if an increase in the numbers of one causes a reduction in the numbers of the other.
compound: substance made up of two or more different types of atoms that have been joined (bonded) together
compression: region in which the particles are closer than when not disturbed by a wave
concave: curved inwards
conducting path: connected series of materials along which an electric current can flow
cones: sensory receptors in the retina that respond to red, green or blue light. Cones are mainly in the central part of the retina.
conscious actions: an action that starts in the brain
conscious response: when thinking takes place, and decisions about which responses are needed are made. Impulses are then sent along appropriate motor neurons to the effectors.
continental crust: the plates of the Earth's crust that make up the land
continental drift: movement of the plates of the Earth's crust in relation to each other
control: in an experiment, any object or person left unchanged to act as a point of comparison
control rods: used to slow or increase the rate of the reaction by absorbing spare neutrons. They are lowered or raised as needed.
controlled variables: the conditions that must be kept the same throughout the experiment
convection: transfer of heat through the flow of particles
convection current: circular movement that occurs when warmer, less dense fluid particles rise and cooler, denser fluid particles sink
convergent evolution: tendency of unrelated organisms to acquire similar structures due to similar environmental pressures

converging lenses: lens that bends rays so that they move towards each other. Converging lenses are thicker in the middle than at the edges.
converging plates: tectonic plates that collide with each other
convex: curved outwards
cornea: clear, curved outer surface of the eye
corrosion: a chemical reaction that occurs between a metal and substances in the air or water around it that causes the metal to be eaten away over time
coulombs: the derived SI unit of electric charge, defined as the quantity of electricity transferred by 1 ampere in 1 second
covalent compound (or molecular compound): the compound formed by the sharing of electrons
covalent bond: shared pair of electrons holding two atoms together
crater lake: a water-filled cone of a volcano
critical mass: an uncontrolled chain reaction can occur only if the amount of radioactive material is over a certain critical mass
crystallisation: the formation of crystals in a solution
dangerous goods: chemicals that could be dangerous to people, property or the environment. They are divided into classes including explosive, toxic, corrosive and flammable.
daughter isotope: an isotope which results from nuclear decay of another isotope; for example, nitrogen-14 is the daughter isotope of carbon-14
decay: to break down by giving out alpha, beta, or gamma rays
decibel scale: used to measure the sound level or loudness of sound
deep focus: an earthquake that occurs between 300 and 700 km from the surface of the Earth
dendrite: relays information towards the cell body of a neuron
deoxyribonucleic acid (DNA): deoxyribonucleic acid, the chemical substance found in all living things that encodes the generic information of an organism. DNA is composed of building blocks called nucleotides, which are linked together in a chain.
dependent variable: variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
deuterium: a hydrogen isotope (hydrogen-2) which contains 1 neutron and 1 proton
diodes: a valve or solid-state device that allows electric current to flow in only one direction through it
diploid: the number of chromosomes found in most body cells
dispersion: separation of the colours that make up white light. Each colour is bent differently when it enters or leaves a glass prism.
distance: a scalar measurement of length expressed only as a size, with no direction
diverge: refract away
divergent evolution: *see* branching evolution
diverging lenses: lens that bends rays so that they spread out. Diverging lenses are thinner in the middle than at the edges.
DNA fingerprint: a person's DNA fragments separated into their specific lengths to form a pattern that may be used to identify an individual or to determine the presence of a particular gene
DNA fingerprinting: involves isolating and separating DNA fragments into their specific lengths to form a pattern that may be used to identify an individual or to determine the presence of a particular gene
DNA hybridisation: technique that can be used to compare the DNA in different species to determine how closely related they are
dominant: refers to a trait that requires only one allele to be present for its expression in a heterozygote
dormant: not currently active, but not regarded as extinct. Dormant volcanoes show no signs of erupting in the near future.
ear canal: the tube that leads from the outside of the ear to the eardrum
eardrum: a thin piece of stretched skin inside the ear that vibrates when sound waves reach it

earthquake: an earthquake may occur when convection currents in the mantle cause the tectonic plates to move past each other, away from each other or underneath one another
echolocation: use of sound to locate objects by detecting echoes
ecliptic: the path that the sun traces in the sky during the year
effectors: structures such as muscles or glands that respond to stimulus
electric circuit: a path for electrons to follow, consisting of a power supply, one or more loads, and conductors joining the power supply and loads
electric current: a measure of the amount of electric charge passing a particular point in an electric circuit every second
electric motor: a device that converts electrical energy into kinetic energy
electromagnetic pulse: burst of electromagnetic activity
electromagnetic radiation: heat, light, X-rays, radio waves and other forms of radiation made up of electromagnetic waves. These waves are produced by the acceleration of an electric charge and have an electric field and a magnetic field at right angles to each other.
electromagnetic wave: electromagnetic energy that is transmitted as moving electric and magnetic fields. There are many different types of electromagnetic energy e.g. light, microwaves, radio waves.
electron cloud: the fuzzy sphere or shell created by electrons moving very fast around the nucleus
electron dot diagrams: diagrams using dots to represent the electrons in the outer shell of atoms. Used to show the bonds between atoms in molecules.
electron shell diagram: diagram showing electrons in their shells around the nucleus of an atom
electron shells: the regions around the nucleus in which electrons are found
electron transfer: movement of electrons from one atom, ion or molecule to another
electrons: negatively charged, very light particles in an atom. Electrons move around the nucleus of the atom.
electrovalency: the number of positive or negative charges on an ion
element: pure substance made up of only one type of atom
endocrine glands: organs that produce hormones. Endocrine glands release their hormones into the bloodstream for transport to target organs.
enhanced greenhouse effect: an intensification of the greenhouse effect caused by pollution adding more carbon dioxide and other greenhouse gases to the atmosphere; associated with global warming
epicentre: the point on the Earth's centre directly above the site where an earthquake originates
eruption: when magma is ejected onto the surface from a volcano
Eustachian tube: tube that joins the middle ear to the nose and throat
excited state: the state in which an atom is after gaining energy. This extra energy can cause electrons to move further away from the nucleus into orbits with bigger radii.
exothermic: chemical reactions that give out heat energy to the surroundings
external radiotherapy: cancer treatment where radiation is directed from an external machine to the site of the cancer
extinct: describes a volcano that has not erupted for thousands of years and shows no signs of future eruption
extinction: complete loss of a species when the last organism of the species dies. The Tasmanian tiger is believed to be extinct but there are still occasional reports of sightings.
fault: a break in a rock structure causing a sliding movement of the rocks along the break
field magnets: permanent magnets that are used to create and maintain the magnetic field in a motor or generator
fission products: products of a nucleus split to form two smaller nuclei
fissure: a weak area of a volcano through which magma may escape
fluoresces: a glow caused by radiation
focal point: the focus for a beam of light rays

focus: point where light rays meet after passing through a lens, or from which they appear to have come before passing through a lens
fold: a layer of rock bent into a curved shape, which occurs when rocks are under pressure from both sides
folding: buckling of rocks caused when rocks are under pressure from both sides
fossil: evidence of life in the past
fossil fuels: substances such as coal, oil and natural gas that have formed from the remains of ancient organisms. Coal, oil and natural gas are often used as fuels; that is, they are burnt to produce heat.
frequency: a number of vibrations each second
friction: the force from one surface rubbing against another
fuse: a safety wire that melts when too much current flows through it. Fuse wires are designed to melt at different currents.
garden lime: combination of calcium hydroxide, calcium carbonate or magnesium carbonate that neutralises some of the soil's acidity
gene: segment of a DNA molecule with a coded set of instructions; may determine the characteristics of an organism
gene pool: all the genetic information for a particular species
genotype: information inherited from the parents and contained in the DNA
geosequestration: the process that involves separating carbon dioxide from other flue gases, compressing it and piping it to a suitable site
geostationary: describes a satellite that remains above the same location of the Earth's surface
gigalitre: a billion litres
global warming: the observed rise in the average near-surface temperature of the Earth
gradient: the slope of a graph
greenhouse effect: a natural effect of the Earth's atmosphere trapping heat, which keeps the Earth's temperature stable. The sun's energy passes through the atmosphere and warms the Earth. Heat energy radiated from the Earth cannot pass through the atmosphere and is trapped.
greenhouse gases: gases found in the atmosphere that contribute to the greenhouse effect, trapping the sun's heat (for example, carbon dioxide)
ground state: the state of an atom when its electrons are in their lowest possible energy levels; that is, not excited
ground zero: the centre of an explosion
gymnosperms: a group of seed-producing plants such as conifers, cycads and ginkgo
half-life: time taken for half the radioactive atoms in a sample to decay; that is, change into atoms of a different element
halogens: non-metal elements in Group VII of the periodic table
hazardous substances: chemicals that have an effect on human health. This effect may be immediate such as poisoning, or long-term like cancer.
hearing loss: any sound above 85 dB can cause hearing loss which is related both to the loudness of the sound and the length of exposure
HIV: Human Immunodeficiency Virus — the virus that causes AIDS. It is transmitted from an infected person to an uninfected person by blood-to-blood contact (e.g. by sharing needles) or during sexual intercourse via semen and vaginal fluid.
homologous structures: body structures that perform a different function but have a similar basic structure
homology: similarity in characteristics that result from common ancestry
horst: a block of rock with faults on both sides. The rock on both sides is lower than the central block.
human dose equivalent (H): the absorbed dose of radiation multiplied by the quality factor (Q)
hydrocarbons: compounds containing only hydrogen and carbon

hydrogen bombs (or H bombs): hydrogen bombs or H bombs detonate in two stages. The first stage involves the explosion of a small fission bomb that creates the necessary high temperatures and the second stage occurs when the superheated hydrogen nuclei combine.
hydrosphere: the water on the Earth's surface
ice cores: samples of ice extracted from ice sheets containing a build-up of dust, gases and other substances trapped over time
igneous rocks: rocks that form from the cooling of lava or magma as it is thrown through the air from a volcanic eruption
image: picture of an object
in series: when devices in an electric circuit are connected directly one after another
inbreeding: production of offspring resulting from the mating of closely related individuals such as cousins, brother–sister, or self-fertilising plants
independent variable: the variable that a scientist changes to observe its effect on another variable
indicators: indicators change colour depending upon the pH of the substance in which they are placed
instantaneous speed: speed at any particular instant of time
insulator: material that does not allow electricity to flow though it easily
integrated circuits: electric circuits made up of miniature components that can be etched onto silicon chips
internal radiotherapy: cancer treatment also known as brachytherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.
International System of Units (SI): an internationally recognised system of metric units, now used as the basis of Australia's metric system, in which the seven base units are the metre, kilogram, second, ampere, Kelvin, mole and candela
interneuron: a nerve cell that carries nervous impulses through the central nervous system. Interneurons provide the link between sensory neurons and motor neurons.
interstitial fluid: the fluid surrounding cells
ionic bond: attractive force between ions with opposite electrical charge
ionic compounds: compounds containing positive and negative ions held together by the electrostatic force
ions: atoms or groups of atoms that have lost or gained electrons
iris: coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye
isotopes: atoms of the same element that differ in the number of neutrons in the nucleus
karyotype: the appearance (size, shape and number) of the chromosomes in a cell
lachrymal glands: glands near the eye that produce tears to wash away dust, dirt and foreign particles
landfills: areas set aside for the dumping of rubbish
lava: mixture of molten rock and gases that has reached the Earth's surface from a volcano
lava fields: areas over which large amounts of basaltic lava have flowed
law of reflection: When light strikes a shiny surface like a mirror, the angle of incidence equals the angle of reflection.
lens: a transparent curved object that bends light towards or away from a point called the focus. They eye has a jelly-like lens.
light-year: the distance that light travels in one year
line transect: method of sampling elements along a linear path in a certain region
linings: inside covering of body openings
liquid crystal display (LCD): thin, flat panel used for electronically displaying information such as text, images and moving pictures
lithosphere: the outermost layer of the Earth; includes the crust and uppermost part of the mantle
live: charged with electricity
load: device that uses electrical energy and converts it into other forms of energy

longitudinal waves: compression waves
long-sightedness: the condition of not being able to see clearly things that are close
luciferases: enzymes involved in the light-producing chemical reaction in fireflies
luciferin: a natural pigment; the key reaction in bioluminescence occurs between luciferin and oxygen
luminol: a chemical that reacts with hydrogen peroxide to produce aminophthalate and light
lymph nodes: filters or traps for foreign particles that contain white blood cells
lymphocytes: small, mononuclear white blood cells present in large numbers in lymphoid tissues and circulating in blood and lymph. They combat microbial invasion, fight cancer and neutralise toxic chemicals.
magma: a very hot mixture of molten rock and gases, just below the Earth's surface, that has come from the mantle
magma chambers: reservoirs in the Earth's crust formed when magma first moves up through weak regions
magnitude: size. Also a measure of the brightness of a star.
main sequence: area on the Hertzsprung–Russell diagram where the majority of stars are plotted. Stars on the main sequence produce energy by fusing hydrogen to form helium. Such stars are at times referred to as being in their 'adult' stage, one of stability.
mass number: number of protons and neutrons in the nucleus of an atom
material safety data sheet (MSDS): a document containing important information about hazardous chemicals
meiosis: cell division process that results in new cells with half the number of chromosomes of the original cell
meltdown: the melting of a nuclear-reactor core as a result of a serious nuclear accident
Mendelian genetics: the analysis of the inheritance of a trait that is controlled by a single gene
meninges: three layers of tissue that surround the brain and spinal cord. It is separated from them by cerebral fluid.
metagenomics: a technology that combines DNA sequencing with molecular and computational biology
metalloids: elements that have the appearance of metals but not all the other properties of metals
metals: elements that conduct heat and electricity; shiny solids which can be made into thin wires and sheets that bend easily. Mercury is the only liquid metal.
metamorphic rocks: rocks formed from another rock that has been under great heat or pressure (or both)
microprocessor: a combination of CPU, memory and other components contained on one computer chip.
microquakes: tremors of magnitudes less than 2.0 on the Richter scale
microwave: an electromagnetic wave of very high frequency, with a wavelength range from 50 cm to 1 cm
mitochondria: small rod-shaped organelles that supply energy to other parts of the cell. They are usually too small to be seen with light microscopes. Singular = mitochondrion.
mitosis: cell division process that results in new cells with the same number of chromosomes as the original cell
molecule: the smallest unit of an element or compound
molecular bond: *see* chemical bond
molecular compound: *see* covalent compound
molecular formula: shorthand statement of the elements in a molecule showing the relative number of atoms of each kind of element
molecular ions: groups of atoms that have an overall charge
Montreal Protocol: an international agreement with the goal of reducing and eliminating the use of substances that contribute to the depletion of the ozone layer
motor neuron: the nerve cell that causes an organ, such as a muscle or gland, to respond to a stimulus
mucus: a thick, slimy liquid produced by the mucous membranes
multicellular: composed of many cells. Most plants and animals are multicellular.
mutagen: agent or factor that can induce or increase the rate of mutations

myelin sheath: a protective layer around the axon of a neuron
natural selection: process by which a species gives rise to new species that has characteristics that make them better adapted for survival in a particular environment. This is also called 'survival of the fittest'.
nebulae: areas of glowing pink, blue and green gas where new stars form
negative ion: atom or group of atoms that has more electrons than protons
nerve: a bundle of neurons
neuron: a nerve cell
neurotransmitter: chemical released from the axon terminals into the synapse between neurons during an impulse
neutral: having the same number of protons and electrons
neutral: neither acidic nor basic
neutron star: extremely dense remnants of a supernova in which protons and electrons in atoms are fused to form neutrons
neutrons: particles with no electrical charge that are found in the nucleus of an atom
Newton's laws of motion: three laws that describe the relationship between the forces acting on a body and the motion of that body
Newton's Second Law of Motion: law that states that the acceleration of an object equals the total force on the object divided by its mass
noble gases: elements in the last column of the periodic table. They are extremely inert.
non-metals: elements that do not conduct electricity or heat; they melt and turn into gases easily, and are brittle and often coloured
normal: a line drawn perpendicular to a surface at the point where a light ray meets it
nuclear energy: the energy stored at the centre of atoms, the tiny particles that make up all substances
nuclear fallout: when radioactive nuclei formed during nuclear reactions as well as tonnes of irradiated dust blasted high into the atmosphere during detonation fall back to Earth
nuclear fission: occurs when the nuclei of large atoms such as uranium or plutonium split to form the nuclei of smaller atoms, releasing energy in the form of radiation and heat
nuclear force: very large force that holds protons and neutrons together in the nucleus of an atom
nuclear fusion: joining together of the nuclei of lighter elements to form another element, with the release of energy
nuclear radiation: radiation from the nucleus of an atom, consisting of alpha or beta particles, or gamma rays
nuclear reactions: reactions involving the breaking of bonds between the particles (protons and neutrons) inside the nuclei of atoms
nucleus: central part of an atom, made up of protons and neutrons
Ohm's Law: statement relating to the change in voltage across a conductor to the change in current. It states that the voltage across a particular conductor divided by the current through it is constant.
opaque: describes a substance that does not allow any light to pass through it
optic nerve: large nerves that send signals to the brain from the sight receptors in the retina
orogeny: the process of mountain-making
oxidation: chemical reaction involving the loss of electrons by a substance
oxygen: a gas in the air that supports life
ozone layer: a layer in the stratosphere, about 25 km above Earth, that has high concentrations of ozone gas. The ozone layer absorbs over 90 per cent of the sun's ultraviolet light.
P-waves (or primary waves): compression waves, moving through the Earth in the same way that sound waves move through air. They are the fastest of the seismic waves.
palaeontologist: a scientist who studies organisms of the geological past as represented by their fossil remains
Pangaea: a super-continent that existed about 225 million years ago. All of the landmasses that existed at this time were joined together to form this super-continent.

parallax error: error caused by reading a scale at an angle rather than placing it directly in front of the eye
parallel: a circuit that has more than one path for electricity to flow through. If one of the paths has a break in it, the others will still work.
pedigree: a purebred animal
Periodic Law: statement made by Mendeleev that elements with similar properties occur at regular intervals when all elements are listed in order of atomic mass
periodic table: table listing all known elements. The elements are grouped according to their properties and in order of the number of protons in their nucleus.
peripheral nervous system (PNS): made up of sensory and motor neurons. It detects and responds to change.
permafrost: soil on or below the surface of very high mountains in the polar regions that is permanently frozen
phenotype: sum of the physical and mental characteristics of an organism at a particular time. Phenotype depends on both the genotype and the environment.
photochromic: describes lenses made from glass that darken in bright light
photosynthetic: describes organisms, such as plants, which use sunlight to create energy
photovoltaic cells: solar cells that convert sunlight into electrical energy using the movement of electrons between layers of 'doped' silicon
phyletic evolution: occurs when a population of a species progressively changes over time to become a new species
physical barriers: physical defences that help prevent pathogens from entering the body (such as skin, nasal hairs, coughing)
pitch: the highness or lowness of a sound. The sound you hear depends on the frequency of the vibrating air.
pitchblende: a uranium-containing mineral
planetary nebula: ring of expanding gas caused by the outer layers of a star less than eight times the mass of our sun being thrown off into space
plasmids: rings of DNA in bacteria
plate tectonics: the theory concerning the movement of the continental plates
polonium: a radioactive element (Po) discovered by the Curies
positive ion: atom or group of atoms with more protons than electrons
positron emission tomography (PET): a nuclear medicine imaging technique employing gamma rays
power supply: a provider of power
precipitate: the solid product of a chemical reaction. Precipitates do not dissolve.
precipitation reactions: reactions where the reactants are solutions and one of the products is a solid
prevailing winds: winds most frequently observed in each region of the Earth
primary colour: any of three colours (usually said to be red, yellow and blue) regarded as basic, and which can produce all other colours by mixing
prism: a regularly shaped solid often made from transparent material such as perspex or glass
products: chemical substances that result from a chemical reaction
protons: positively charged particles found in the nucleus of an atom
pulsar: a spinning neutron star. Pulsars can be detected using radio telescopes.
pupil: a hole through which light enters the eye
pyroclastic material: ejected material such as cinders, ash and volcanic rocks
quality factor (Q): the strength of differing types of radiation
quasars: one of many extremely distant, very massive sources of high-energy radio-frequency electromagnetic radiation, of unknown structure.
radiant heat: heat energy transmitted via electromagnetic waves
radiation: a method of heat transfer that does not require particles to transfer heat from one place to another

radicals: complex ions called molecular ions such as hydroxide ions OH^-
radio telescope: a telescope that can detect radio waves from distant objects
radioactive: having, relating to, or caused by radioactivity
radiotherapy: the use of radiation such as X-rays or the radiation produced by decaying isotopes to kill cancer cells or prevent them from spreading
radium: radioactive element (Ra) discovered by the Curies
rarefaction: region in which the particles are farther apart than when not disturbed by a wave
rays: narrow beams of light
reactants: the original substances present in a chemical reaction
reactivity: a measure of how likely a particular metal is to take part in a displacement reaction
recombinant DNA technology: technology that can form DNA that does not exist naturally, by combining DNA sequences that would not normally occur together
rectifier: device that changes alternating current to direct current
red giant: star in the late stage of its life. Red giants are cooler than main sequence stars and in their core helium is fused to form carbon and other heavier elements.
red shift: results from a star's movement away from the Earth
redox reaction: a chemical reaction involving oxidation and reduction; that is, electron transfer
reduction: removal of a metal from a mineral. Minerals are compounds containing metal and other elements. Reduction involves adding electrons to metal ions.
reflex actions: processes and actions that occur in the body without conscious thought, such as breathing
reflex arc: a nervous pathway involving a small number of neurons. A reflex occurs when nervous impulses travel from the receptor to the spinal cord and, then, to the effector organ.
refraction: change in the speed of light as it passes from one substance into another. It usually involves a change in direction.
relative atomic mass: a number that compares the mass of atoms to an agreed mass; such as 12 of the mass of a carbon-12 isotope
remote sensing: data collection about Earth's biosphere completed from space by devices such as satellites
resistance (*R*): measure of the electrical energy required for an electric current to pass through as object. The energy is change to heat.
resistors: circuit components that have resistance
respiration: the process by which your body gains energy by breaking down glucose, using oxygen and creating carbon dioxide and water; a slow combustion reaction
retina: curved surface at the back of the eye. It is lined with sight receptors.
Richter scale: a scale that measures the amount of energy released during an earthquake
rift valleys: part of the Earth's crust that has sunk down between two faults
rotor coils: coils of a motor that turn when a current flows through them
S-waves (or secondary waves): waves that travel in the form of transverse waves out from an earthquake. They are slower than P-waves. The ripples on the surface of a pool when a rock has been dropped into it form transverse waves.
safety switch: safety device that opens a circuit if it detects current leakage
salivary glands: glands in the mouth that produce saliva
satellite: object that orbits another object. The Moon is the Earth's satellite. Scientists have made and launched many artificial satellites.
scalar: having only magnitude (size), with no direction
scattered: describes light sent in many directions by small particles within a substance
secondary colours: describes colours produced by combining the three primary colours
sedimentary rocks: rocks formed from sediments deposited by water, wind or ice. The sediments are cemented together in layers, under pressure.
seismic waves: waves of energy that travel through the Earth's crust, caused by earthquakes

seismogram: the output from a seismometer which shows P-, S- and L-waves appearing as a continuous sequence of wriggles
seismograph: an instrument used to detect and measure the intensity of an earthquake
seismometer: a device that detects movement of the Earth
selective agents: the different living (biotic) and non-living (abiotic) agents that influence the survival of organisms
semicircular canals: three curved tubes, filled with fluid, in the inner ear that control your sense of balance
sensory neurons: a nerve cell in the sense organs. It detects change in the environment and sends a message to the central nervous system.
sewage effluent: waste matter which passes through sewers
short circuit: a small circuit that conducts electricity very easily. Short circuits can start fires because of the heat they generate.
short-sightedness: unable to see clearly things that are far away
sievert (Sv): SI (International System of Units) derived unit of dose equivalent radiation
skin: external covering of an animal body
solar system: the sun and all the bodies that revolve around it, such as planets and asteroids
solutes: substances that are dissolved in the solvent to form a solution
solution: mixture of a solute dissolved in a solvent. Solutions are clear but may be coloured.
solvent: substance in which a solute dissolves to form a solution
sound waves: a series of compressions (a region of air particles that are close together) and rarefactions (a region of air particles that are spread apart
speciation: the formation of new species
species: a group of animals with many features in common. Members of the same species can mate with each other to produce fertile young under natural conditions.
spectator ions: ions that are not involved in ion transfer during a chemical reaction
spectrum: light from a source separated out into the sequence of colours, showing the different frequencies
spinal cord: main nerve cord carrying nervous impulses to and from the brain. It is protected by the vertebrae of the backbone.
stable: a nucleus that does not change spontaneously. The protons and neutrons in the nucleus are held together strongly.
stimulus: change in the environment that can be detected and responded to
stomach: a large muscular organ that churns and mixes the food. The stomach lining releases chemicals that start to break down protein.
stratosphere: the second layer of the atmosphere up to about 55 km above the Earth's surface, between the troposphere and the mesosphere
strong nuclear force: the force by which protons and neutrons of the nucleus are held tightly together
structural formula: diagram showing the arrangement of atoms in a substance with covalent bonds drawn as dashes
subduction zones: the area where the oceanic plate sinks under the lighter continental plate
super giants: very large stars that are expanding while running out of fuel, and will eventually explode
supersaturated: a solution that has more solute dissolved in it than is predicted at a particular temperature
surface waves: L-waves are surface waves and travel around the Earth. They travel much more slowly than either the P-waves or S-waves.
suspensory ligaments: bands of collagen that connect the lens to the ciliary muscles
switching centre: switches mobile phone calls to other base stations or to a fixed telephone system
syncline: a downward, U-shaped fold in rock layers

synthesis reaction: a combination reaction (also known as a synthesis reaction) is one in which two reactants produce a single product, usually accompanied by a release of energy in the form of heat and/or light
tailings: solid waste products from metal extraction
target cells: cells in the body that respond to a particular hormone
therapeutic cloning: the production of cells that might be used for research or to produce organs for transplant
thermal: heat energy
thermal energy: heat energy
thermal flash: the enormous amounts of heat and radiation that spread out from the centre of the blast when nuclear weapons are detonated
thermal pollution: heat released into the atmosphere causing an increase in the temperature of the environment
thinking: active consideration involving the brain neurons
thrust: forward push
tissue: a group of similar cells working together to do a particular job in an organism, e.g. nerve tissue, connective tissue
total internal reflection: complete reflection of a light beam that may occur when the angle between a boundary and a beam of light is small. The light must be travelling internally in the glass for a glass–air boundary to cause total internal reflection.
traits: the features or qualities that set something apart from others
transform faults: a fault where movement is sideways, that is, where the blocks of crust slip horizontally past each other
transformer: device that can increase or decrease voltages for alternating current
transgenic: organism with a foreign, introduced gene
transistor: a component that acts like a switch, changing the size or direction of electric current as a result of very small changes in the voltage across them
transition metals: metallic elements that form a block in the middle of the periodic table
translucent: allowing light to come through imperfectly, as in frosted glass
transmitting antenna: metal structure in which vibrating electrons cause radio waves to travel through the air
transparent: describes a substance that allows most light to pass through it. Objects can be seen clearly through transparent substances.
transpiration: loss of water from plant leaves through their stomata
transverse wave: wave involving the vibration of particles perpendicular to the direction of energy transfer
triangulation: method of determining the position of the epicentre of an earthquake by using readings from at least three different seismic stations
tritium: a hydrogen isotope (hydrogen-3) that contains 2 neutrons and 1 proton
troposphere: the layer of the atmosphere closest to the Earth's surface. The particles of the air are packed most closely in this layer and they spread out further away from the surface.
tsunamis: a powerful ocean wave triggered by an undersea earth movement
tumour: an abnormal growth
uncontrolled chain reaction: all of the released neutrons cause further reactions, releasing devastating amounts of energy (mainly in the form of heat and light) and radiation
universal indicator: a mixture of indicators that changes colour as the strength of an acid or base changes, indicating the pH of the substance
valency: equal to the number of electrons that each atom needs to gain, lose or share to fill its outer shell
variable resistor: device for which the resistance can be altered

variables: quantities or conditions in an experiment that can change

variation: amount or rate of change

vector: organism used to transmit genes or disease

velocity: a measure of rate of change in position. Unlike speed, it has a direction as well as a magnitude.

visible spectrum: different colours that combine to make up white light; they are separated in rainbows

vitrification: method of storing or disposing of radioactive waste where liquid radioactive waste is mixed with glass and poured into steel drums

volcanic bomb: large rock fragment that is blown out of erupting volcanoes

vulcanologist: a scientist who studies volcanoes

waveform: a graph on the CRO screen that depicts sound waves

weighted mean: average mass of an element that is calculated from the percentage of each isotope in nature

white dwarf: the core remaining after a red giant has shed layers of gases. A white dwarf has no nuclear reactions and its only energy source is gravity that pulls it into a core of very dense matter, a jumble of tightly packed electrons, protons and neutrons.

X-rays: high energy electromagnetic waves that can be transmitted through solids and provide information about their structure

zodiac: twelve constellations that ancient Greek astronomers believed had a special significance

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